313 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

# HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

## APPLE WATCH
WILL THIS GADGET CHANGE YOUR LIFE?

## SMARTEST ANIMALS
Measuring animal intelligence

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HOW EATING POWERS YOUR BODY

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## END OF THE SUN
The lifecycle of our nearest star

+LEARN ABOUT
JELLYFISH BARBER SURGEONS
PHOTOSYNTHESIS STORMS

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ISSUE 65


**Xduro AMT pro 27.5**

27.5", All Mountain, 150mm travel, 4-Link System • Bosch Performance 36 Volt, 250 Watt Motor, 60Nm Torque
Lithium Ion 400Wh Battery, max range 175km • Bosch Intuvia Display • Sprocket Equalizing System • Gravity Casting Interface • Skid Plate Motor Protection
Fox 34 Talas CTD Adjust FIT 120-150mm / Fox CTD Kashima • Sram X01 11-speed • Avid X.0 Trail Hydraulic Disc Brakes • Crank Brothers Iodine 3 Wheelset • 21.1kg

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ISSUE 65

# WELCOME

The magazine that feeds minds!

**Page 72**
Learn all about how the aurora borealis form, and why it's only visible close to the pole

*Doctor Who* fans might recall the David Tennant episode *Gridlock*. It was pretty memorable – about a far-future traffic jam with flying cars and humanoid cats at the wheel. Planning our cover feature reminded me of that. The technology that is being developed for road vehicles is simply insane.

One concept car comes with a drone companion, which can fly off ahead to discover why you've been stuck in a queue for so long. Another vehicle is more like a hospital on wheels, with heartrate monitors and stress sensors in the seats. Flip to page 12 to find out more of what the future holds. There aren't any cat-people, but we do have a feature on the planet's smartest animals if you'd like to see some clever furry faces.

This issue, we also discover the amazing journey of every mouthful. You'll find out why it takes 48 hours to digest a meal, why children hate vegetables and exactly how long your digestive system is (hint: it's a lot taller than you!).

Hope you enjoy the issue.

Jodie

**Jodie Tyley**
Deputy Editor

## Meet the team...

**Andy**
**Art Editor**
The Romans have always fascinated me so I particularly enjoyed reading up on the Pantheon on page 74.

**Erlingur**
**Production Editor**
If you want to admire the power of the cosmos (or like feeling utterly insignificant), then read our feature on the death of stars on page 56.

**Jamie**
**Staff Writer**
The Crown Jewels are an iconic piece of British history. Discover their amazing story over on page 79.

**Jackie**
**Research Editor**
Find out how lost keys and forgotten passwords could be a thing of the past in the identity detectors feature.

**Hannah**
**Assistant Designer**
Learn more about your digestive system and why you crave certain foods in our Food and your body feature on page 24.

**Jack**
**Staff Writer**
Take a look at the new kid on the Royal Navy block, the immense and breathtaking HMS Queen Elizabeth aircraft carrier.

## What's in store

**Check out just a small selection of the questions answered in this issue of How It Works...**


How do parachutes stop us from falling? **Page 32**


Which is the smartest animal on the planet? **Page 64**


What's it like on board the HMS Elizabeth? **Page 20**


How do fingerprint scanners identify you? **Page 38**


What is the weather like on planet Jupiter? **Page 61**


How do you tell the age of dinosaur bones? **Page 76**

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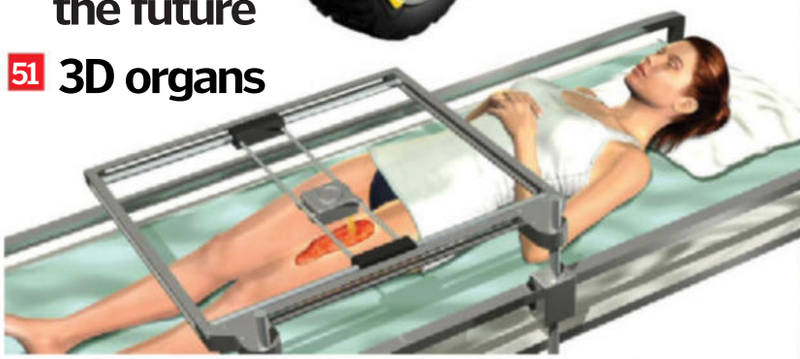
## 12 CARS OF THE FUTURE

Discover how flying drones, virtual assistants and LED wheels will revolutionise the roads






## Meet the experts...

**Laura Mears**
**Food and your body**
This month, Laura unravelled all nine metres of the digestive system to reveal the journey of every mouthful. You'll also discover why you crave certain foods (like chocolate!) on page 24.

**Hayley Paterek**
**Smartest animals**
Our resident wildlife expert counts down some of the most intelligent critters on the planet. Find out who made the top ten over on page 64 – some may surprise you!

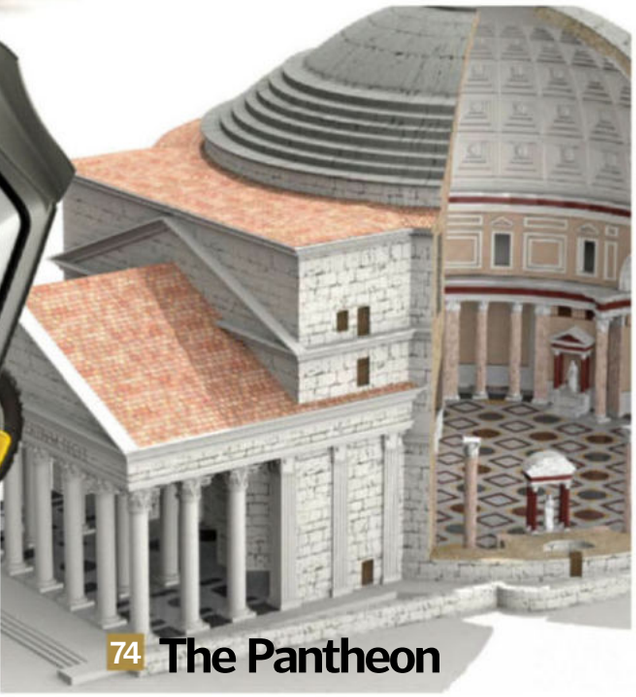
**Lee Sibley**
**Cars of the future**
Who better to talk us through the crazy new cars coming our way than our very own Stig, Lee? The future will amaze you – there are flying drones and sensors that monitor your health – all on page 12.

**Alicea Francis**
**Steve Jobs**
Alicea recounts how Steve Jobs – the late, great founder of Apple – revolutionised the world of tech with his dream to create a computer you could hold in your hands.

**Gemma Lavender**
**End of the Sun**
It's hard to imagine a time when the Sun won't exist, but you can find out its unbelievable fate in Gemma's feature on page 56. Don't worry, our nearest star still has a few billion years left.

Are footballers the way forward for renewable energy?
Find out on pg 10

# REGULARS



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76 Dinosaur bones



# Supersized sewer

## The gigantic drainage tunnel that could save 'sinking' Mexico City

110 metres (360 feet) below the capital of Mexico lies this half-complete tunnel, the 'Túnel Emisor Oriente', which will be added to a mega sewer system that will help prevent flooding and keep the city from sinking. Mexico City is built on top of a drained lakebed and has borne the brunt of poor conservation management and overpopulation. The project has been troubled by various financial problems after being initially scheduled for a 2012 completion. Recently, it has received a substantial investment and will open in 2018 and hopefully end the city's sinking feeling.

### The statistics...

**Túnel Emisor Oriente**

**Length:** 62km (39mi)
**Discharge:** 150m³ (5,300ft³)
**Height:** 56m (184ft)
**Cost:** 15 billion peso (£700 million / $1.1 billion)

Plaza de la Constitución in Mexico City

# Other sinking cities

## Could we soon have a real-life Atlantis?

**Venice**

The 'City of Water' is constantly sinking, with floods a common occurrence. Statistics suggest the city could drop by 8cm (3.15in) in the next 20 years, so counter-measures are being set up.

**Southeast England**

Although not strictly a city, in counties such as Sussex and Kent experts predict the land will sink by at least 5cm (2in) in the next 100 years. This is an after-effect of the ice sheets melting at the end of the last Ice Age.

**New Orleans**

Ravaged by Hurricane Katrina in 2005, the city of New Orleans may soon be facing another threat. Many believe the city could be off-shore within 90 years as the sea closes in around it.


The new release sees the iPhone at its largest and thinnest

# Apple Watch

## Technology giant bites into wearable devices

The Apple Watch sees the tech giant enter the world of wearable gadgets. Aiming to be an all-round everyday essential, the device can play music like an iPod, send and receive calls and act as a fitness tracker. According to Apple, four sapphire lenses on the back promise to measure your heart rate more accurately than other smartwatches. The tech giant has also invested in customised fitness apps that track calories, moderate activity and – when paired with an iPhone – track your distance travelled via GPS or Wi-Fi. The Apple Watch also enables you to access other apps, as well as make payments via the new Apple Pay system and even control your Apple TV and connected smart home devices – all from your wrist.

The Apple Watch will also double as a fitness tracker with its own accelerometer and heart-rate monitor

# Bigger and better?

## The iPhone 6 has arrived and it's available in Plus size

The eighth generation of iPhone has seen Apple embrace the trend of the 'phablet' – a smartphone that's almost the size of a tablet. Dubbed the iPhone 6 Plus, it has a 14-centimetre (5.5-inch) screen, yet is only 7.1 millimetres (0.28 inches) thick. It arrives alongside a smaller version – simply called the iPhone 6 – which has a 11.9-centimetre (4.7-inch) screen and is only 6.9 millimetres (0.27 inches) thick. Both come with a host of new features, including full-HD video recording with a slo-mo option, and three times faster speeds when connected to Wi-Fi.

The handset has already broken pre-order records with more than 4 million people signing up for the new product.

### The sta...tics...

**iPhone 6**

**Screen size:** 11.9cm (4.7in)
**Resolution:** 1334 x 750
**CPU:** A8 Chip
**Battery life:** up to ten days (standby)
**Camera:** 1080p HD
**Capacity:** up to 128GB

**iPhone 6 Plus**

**Screen size:** 14cm (5.5in)
**Resolution:** 1920 x 1080
**CPU:** A8 Chip
**Battery life:** up to 16 days (standby)
**Camera:** 1080p HD
**Capacity:** up to 128GB

# Snow tunnel discovered in Scotland

## A 120m tunnel formed after heavy winter snowfall

It seems last winter's heavy snowfall did more than cause transport issues up and down the UK. A spectacular snow tunnel has been found at the Drumochter Pass in the Scottish Highlands. The 120-metre (394-foot) tunnel has a vivid patterned ceiling and was created when heavy snow formed a drift over a stream. Its northwestern angle means it has survived through the summer months due to a lack of direct sunlight during daytime hours.

A surfer looks on as a thunderous wave hits the coast of Sydney

# Surf's up

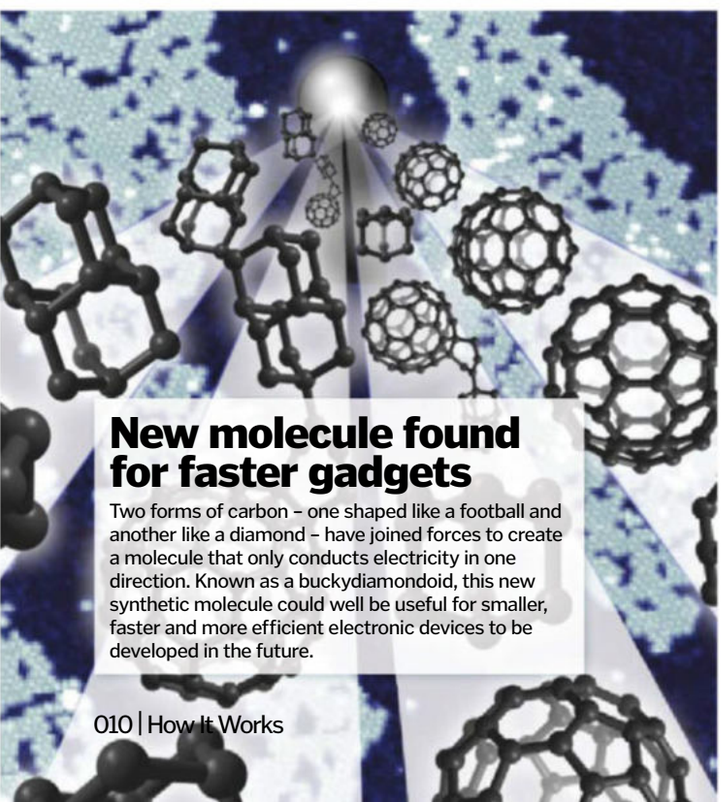
## Tropical storms create enormous waves in Sydney

Sydney, Australia, is known for its impressive surf, but the waves aren't usually quite this big. The beaches to the north of the city have been battered by a recent eight-metre (26-foot) swell in waves. The increase in size is down to intense tropical storms off the coast of Australia, where prolonged winds created swells in the sea. At the time of writing, a severe weather warning has been issued by the Bureau of Meteorology as these huge waves continue to strike the beach.

# 10 COOL THINGS WE LEARNED THIS MONTH

## Trout are as clever as chimps

Fish aren't usually considered the brightest of animals but intelligent hunting behaviour, only witnessed before in humans and chimpanzees, has now been seen in coral trout and eels. The trout chases the prey into a narrow gap while the eel lies in wait. The trout benefits by feasting on the victims the eel fails to catch.



## New molecule found for faster gadgets

Two forms of carbon – one shaped like a football and another like a diamond – have joined forces to create a molecule that only conducts electricity in one direction. Known as a buckydiamondoid, this new synthetic molecule could well be useful for smaller, faster and more efficient electronic devices to be developed in the future.

## Rice is dried on Chinese roads

Chinese farmers have found that one of the most effective ways to dry huge quantities of rice is to lay it down in the middle of a street and use the draft of passing vehicles to remove moisture from the grains after the harvest.

## Mammals existed 160 million years ago

New fossil evidence has shown that squirrel-like creatures scurried around Earth over 160 million years ago, 40 million years before it was believed mammals first existed. They are part of a new Euharamiyida group that shared the world with dinosaurs.

## Babies can go on a spa break

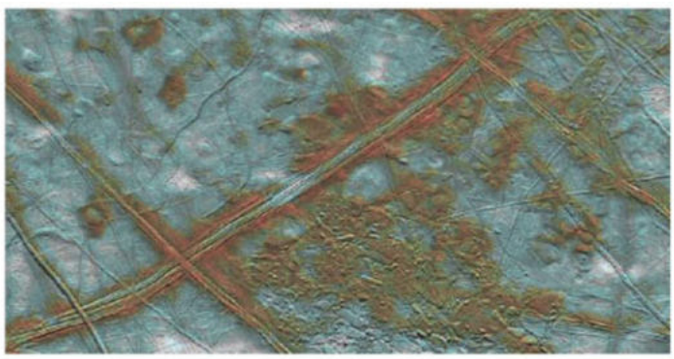
We all love a good soak once in a while, but don't babies deserve one too? The Float Baby Spa in Texas is the first-ever baby spa in the USA and will allow infants to take a supervised dip in purified water before drying off in anti-microbial towels and getting a massage. Over 300 babies as little as two weeks old have taken the dip since it opened earlier this year.

## Footballers can produce electricity

A football pitch in Rio de Janeiro can harness the kinetic energy given off by players. When one of the 200 energy-capturing tiles is stepped on, a series of cogs turn an electric generator. It is hoped that this system can power even larger areas in the future with tiles already in use in airports and shopping centres.

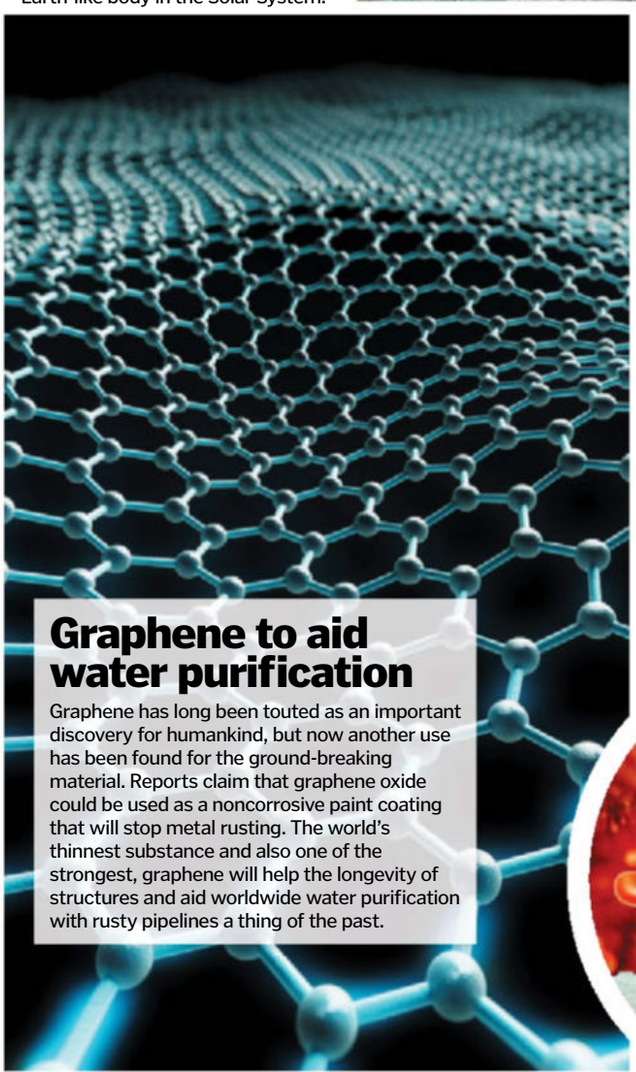
## Europa is more Earth-like than we think

Jupiter's moon Europa has always been seen as a possible location of alien life and now geological activity has been spotted on the satellite as well. Scientists have now witnessed old crust being destroyed to make way for new icy plates. Europa's surface is riddled with tectonic ridges and cracks and is the most Earth-like body in the Solar System.



## Monkeys have specialised brains

The social order of monkeys may be more intricate than previously thought. A new discovery suggests that primate minds differ depending on their place in a hierarchy. The study looked at macaques and found that particular areas of their brains were different depending on their role. A similar study also showed that monkeys in the middle of the hierarchy displayed signs of 'middle manager' stress.



## Graphene to aid water purification

Graphene has long been touted as an important discovery for humankind, but now another use has been found for the ground-breaking material. Reports claim that graphene oxide could be used as a noncorrosive paint coating that will stop metal rusting. The world's thinnest substance and also one of the strongest, graphene will help the longevity of structures and aid worldwide water purification with rusty pipelines a thing of the past.

## A new way to battle flu

A new therapeutic shot has been approved for use in Japan and South Korea to cure the symptoms of flu. The injection works using neuraminidase, a viral protein contained in bacteria. The drug is known as peramivir and its creators at the University of Alabama say that it will be most suited to people who are already hospitalised or are immune-compromised.

# CARS OF THE FUTURE

## DISCOVER THE UNBELIEVABLE NEW TECH TRANSFORMING THE AUTOMOBILE INDUSTRY

**Toyota FT-1**
This sports car model captures the energy we can expect from Toyota's future designs.

**Ford C-Max Solar Energi**
Ford's baby people carrier is the first of its kind to get energy straight from the Sun, thanks to roof-mounted solar cells that gather and store energy.

**Rimac Concept One**
This pure electric vehicle boasts a sensational 1,088hp, making it one of the world's fastest-accelerating electric automobiles.

# HEAD 2 HEAD
## EXTREME CONCEPTS

**1. SMALLEST**

### Toyota FV2

The compact FV2 stands only 99cm (39in) from the ground and is a mere 1.6m (5.2ft) wide. Blink and you'll miss it!

**2. LONGEST**

### MAN Concept S

The streamline Concept S exceeds current EU truck length limits at over 16.5m (54ft) long, but MAN has plans to lobby for this legislation to be changed.

**3. FASTEST**

### Rimac Concept One

The all-electric hypercar can sprint from 0-100km/h (0-60mph) in just 2.8 seconds before reaching a top speed of 305km/h (190mph).

**DID YOU KNOW?** *You can experience what driving and controlling a Toyota FV2 is like with the FV2 app, available on iTunes*

The world of the motor vehicle is fast evolving. In fact, ever since the very first patent for a passenger vehicle with an internal combustion engine was filed by Karl Benz in 1886, cars have never stopped developing, often in unexpected ways.

Early breakthroughs in the industry have helped shape what we conceive a passenger vehicle to be today: just take the invention of pneumatic tyres on vehicles in 1895, the automatic gearbox in 1904 and the aerodynamics-enhancing rear spoiler in 1973 as notable cases in point.

However, in our digital age, the rate of automotive innovation has never been more rapid, with manufacturers constantly lavishing their vehicles with cool new technologies to make them faster, safer, more economical and more interactive than ever before. Much of this is down to computer technology being integrated into the vehicle.

A computerised ECU (Engine Control Unit) was first introduced on a vehicle in the 1970s to better match the amount of fuel mixing with air to ignite in the engine and power the car along the road. In the 40 years since, these have evolved enormously – despite getting smaller in size – and are now very much the all-seeing eye of a car.

A modern ECU controls various parameters on the vehicle, including different performance maps for the engine, traction control, fuel efficiency, and even when to deploy aerodynamic aids such as spoilers or to automatically turn on night-driving lights and rain wipers in some cases. With a car's ECU now taking care of more and more tasks and actions, driving a car has never been easier or safer, with the presence of computers reducing the risk of human error at the wheel.

The car industry's habit of cramming technology onto a car using even smaller space simply means there's no end to the possibilities of the evolution of the motor vehicle. With this in mind, it's almost impossible for anybody to predict what vehicles will look like, sound like and even drive like by the turn of the 22nd century. However, thanks to the exciting array of technologies introduced on manufacturers' contemporary vehicles and concept cars, we can at least have some idea of what's in store for cars of tomorrow.

The obvious change for vehicles of the future is a forced one: with Earth's supply of fossil fuels quickly diminishing, vehicles will no longer be able to rely on gasoline as a fuel source. Therefore, finding alternative means of power is a common goal for all manufacturers, with hybrid engines and even fully electric-powered vehicles now a common sight on the road. But fuel is just the start of this age of innovation – and the beginning of the excitement for consumers...


## BMW i8 concept and production vehicle

**This car can be connected to your smartphone**

### BMW's i Remote app

This app for iOS and Android shows you current information about the status of your BMW i8, including charging status of its battery, as well as efficiency.

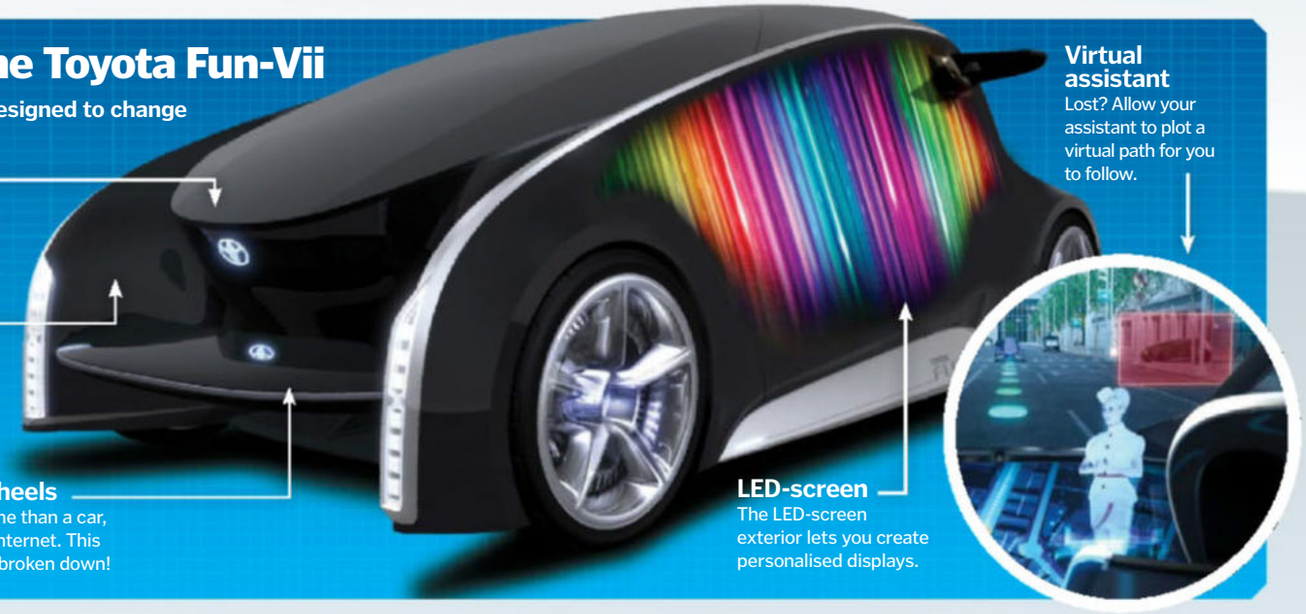
"Concept cars are one-off project ideas used to showcase creative and technological capabilities"

# CONCEPT DESIGNS

While international motor shows are famed for providing a platform for manufacturers to reveal new and updated vehicles to the public for the first time, concept cars are usually flaunted too. Often wacky and overtly outlandish in their design, concept cars are examples of one-off project ideas used to showcase the creative and technological capabilities of a manufacturer. Concept cars are largely inoperable to the capacity of a conventional road-going vehicle, and can appear incomplete, by having no interior, for example. As mere primitive creations, the vast majority of concept cars never make it to mass production, though some aspects of their design and technologies can find their way onto future iterations of mass-produced vehicles. As such, while whole concept cars shouldn't be taken too seriously by the public, their tech should: these cars are often clad with early renditions of futuristic tech that manufacturers intend to refine further for mainstream use. The Chevrolet Volt is perhaps the most famous example of this: debuting at a 2007 show as GM's first interpretation of a plug-in vehicle powered by an alternative fuel source, a much-revised Volt survived full preproduction testing and made it to showrooms worldwide by 2012.


## A ride in the Toyota Fun-Vii

**A concept vehicle designed to change inside and out**



RECORD BREAKERS
ELECTRIC SPEED

# SIX

## PEUGEOT EX1 SPEED RECORDS

Peugeot took its electric EX1 concept car further than most by breaking an amazing six different speed records over distances of 0.2 to 1.6km (0.125 to 1mi), before taking the Nurburgring lap record for an electric vehicle weighing under one ton. Despite this, the EX1 has not yet made it to production.

**DID YOU KNOW?** *Some car insurers in the UK are now offering reduced premiums on cars with predictive emergency braking*

# CONNECTIVITY FEATURES


In our contemporary age of ever-increasing interaction with digital technologies, the car industry is leading the way with clever connectivity features to enhance our entertainment and even safety in a vehicle.

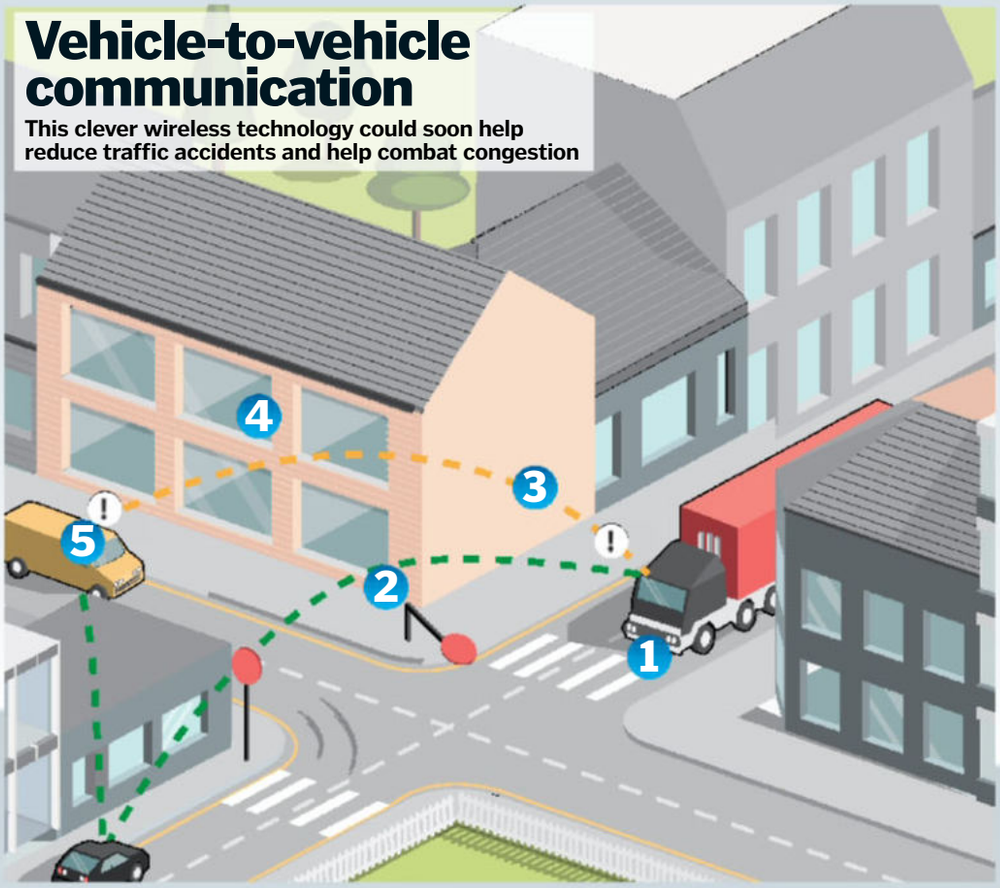
Until recently, connectivity features in a car meant being able to link up your smartphone's phone book to your on-board communication system via a Bluetooth connection, which then enabled you to make hands-free calls while on the move, but little else.

However, technological innovations now mean connectivity takes care of far more than that. Contemporary car connectivity enables you to continue to perform multiple daily tasks, usually performed by your smartphone, simply repackaging it into a safer and more user-friendly experience befitting the environment in a car. For example, now texts, tweets and Facebook messages received by your smartphone can be read aloud to the driver through the vehicle's automated voice system, and even streaming your favourite playlists through your car's speakers is the norm while actively monitoring traffic behaviour or checking the weather. Not all apps are purely for entertainment purposes either: further iterations of the connectivity technology mean you can even start your car remotely – perhaps allowing the car to warm up before you leave the house on frosty mornings – and track your vehicle via smartphone apps (ideal for parents who lend their car to their teenage children), while driver-based apps can monitor your heartbeat and stress levels while you're at the wheel.

This all contributes to a revolutionary new environment where the driver can have access to a wealth of live information while being able to constantly communicate with others and even indulge in music and podcasts without having to take their eyes off the road.

## Vehicle-to-vehicle communication

**This clever wireless technology could soon help reduce traffic accidents and help combat congestion**




**1 The scene**
Both vehicles are travelling toward an intersection, unaware that another vehicle is also approaching.

**2 Hazard perception**
As the stop sign has been knocked down, a human may not realise they are required to stop at the junction, and so an accident could happen.

**3 Vehicle communication**
With this innovative new technology, each car emits a signal, which is picked up by the other vehicle, ensuring both cars are aware of each other's presence.

**4 Notification**
If another vehicle is notified as a significant potential hazard, the driver is alerted via an automated message, making them aware of the danger.

**5 Action**
If one vehicle gets too close to another, the brakes are automatically applied by the system.

## Designing the future

**Design chief Michael Mauer discusses the design process at Porsche**

**How long does it take to design a car?**
**Michael Mauer:** It varies from project to project, and there are lots of factors to consider: is it a completely new car with new technology integrated into it, or is it a revision of a current model?

**Is the design process rewarding?**
**Mauer:** Everyone who designs a car feels great responsibility, as it is the first part of a new vehicle that people see, and helps form that first impression. In the case of the 911, we know we are dealing with something very special as the car has such a great history. There's a great desire to design the perfect package each time, to optimise. It's not uncommon for designers to argue over one kilogram of weight here, or mounting something one centimetre lower there.

**How important is the engineering side of new cars?**
**Mauer:** Very important, particularly as there's an environmental aspect to be very cautious of today. This is undoubtedly the future so the challenge at Porsche is to build cars that are not only environmentally friendly, but also do not lose their performance edge.

**How crucial is branding?**
**Mauer:** Very. With Porsche, whatever we do with the 911, you have to consider how it will affect the rest of the products in terms of technology and design. Iconic cars such as the 911 must have signature elements to it, but it must also evolve to stay interesting and keep up with competitors. However, you shouldn't change for the sake of changing; you should change for the sake of getting better.

"Ford has released details of active seats that can monitor your heart rate or blood sugar levels"

# SAFETY TECH

As well as innovative technologies helping to make our experience with cars easier and more comfortable, there is constant research and development going in to making our cars safer too.

Now a long way away from the humble air bag, car safety has developed to more intricate systems including traction control, ABS (anti-lock braking system) and even predictive emergency braking. To help with vision, cameras are replacing mirrors to reduce blind spots, and new laser headlamp technology is being piloted by German giants Audi and BMW, which offers twice the illumination range of LEDs for night driving.

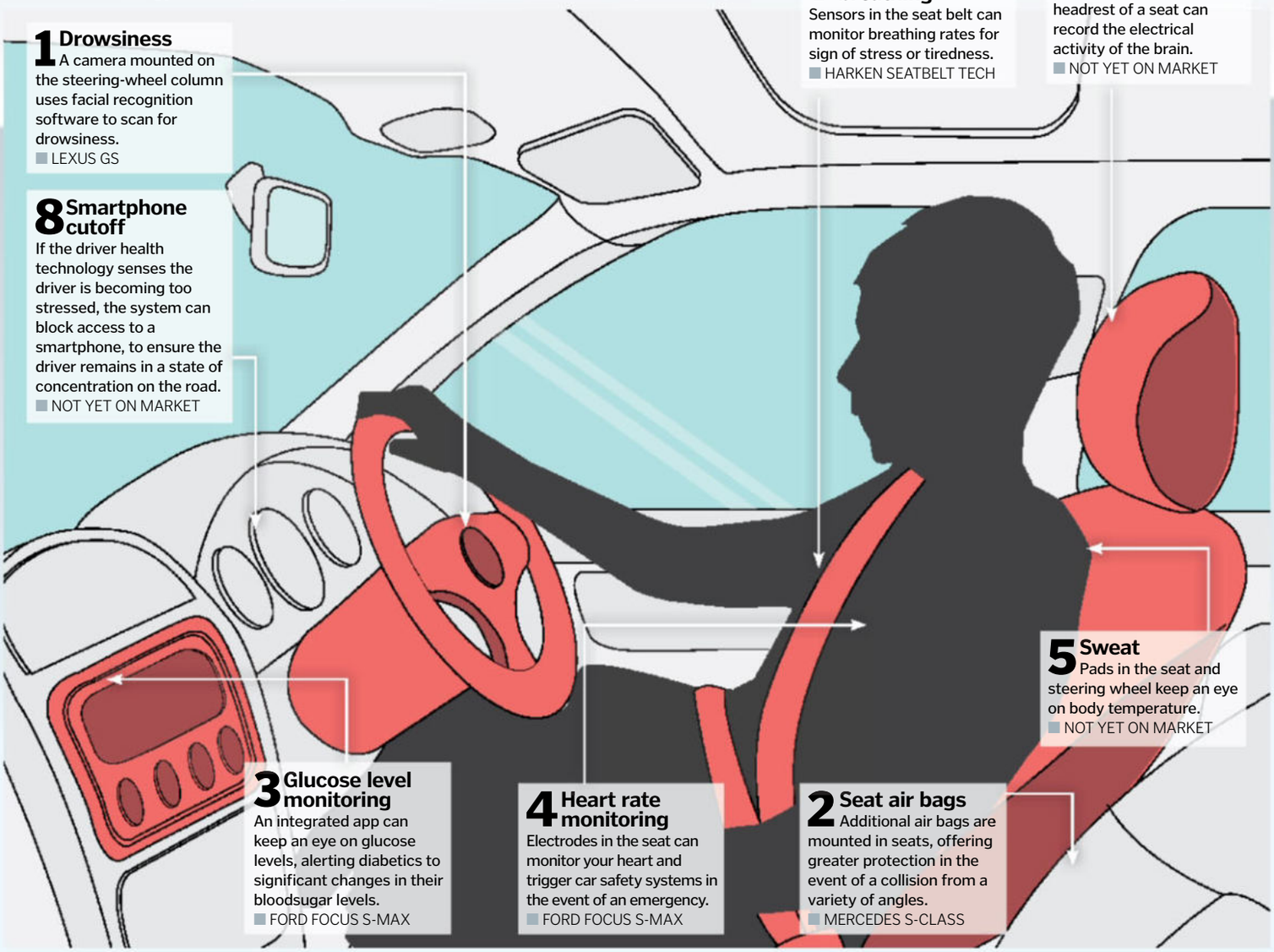
However, current schemes being implemented inside a vehicle for increased safety are even more finite then that: think seat belts that have sensors embedded in them to monitor breathing for signs of stress at the wheel, for example.

And, far from being a distant technology melded to a wild concept car, these safety features are being brought into mass production. As a case in point, the US motor company Ford has released details of active seats that can monitor your heart rate or blood sugar levels, which can then call for medical help if the readings become hazardous.

Of course, the pinnacle of car safety tech is being piloted not by a car manufacturer, but a technology giant: Google has long been experimenting with autonomous systems, even testing its very own fully autonomous vehicle on the roads of California. Autonomous cars use an array of car-mounted lasers, radars and cameras to successfully travel along a road, seen by some as more consistently reliable than a human that can become distracted for fatigued and make errors (you can read more about autonomous vehicles in issue 63).

## Evolving driver safety technology

**Vehicle technology currently in testing monitors your health as well as your safety**



**1 Drowsiness**
A camera mounted on the steering-wheel column uses facial recognition software to scan for drowsiness.
■ LEXUS GS

**2 Seat air bags**
Additional air bags are mounted in seats, offering greater protection in the event of a collision from a variety of angles.
■ MERCEDES S-CLASS

**3 Glucose level monitoring**
An integrated app can keep an eye on glucose levels, alerting diabetics to significant changes in their bloodsugar levels.
■ FORD FOCUS S-MAX

**4 Heart rate monitoring**
Electrodes in the seat can monitor your heart and trigger car safety systems in the event of an emergency.
■ FORD FOCUS S-MAX

**5 Sweat**
Pads in the seat and steering wheel keep an eye on body temperature.
■ NOT YET ON MARKET

**6 Brain waves**
Sensors in the headrest of a seat can record the electrical activity of the brain.
■ NOT YET ON MARKET

**7 Detects breathing**
Sensors in the seat belt can monitor breathing rates for sign of stress or tiredness.
■ HARKEN SEATBELT TECH

**8 Smartphone cutoff**
If the driver health technology senses the driver is becoming too stressed, the system can block access to a smartphone, to ensure the driver remains in a state of concentration on the road.
■ NOT YET ON MARKET

**AMAZING VIDEO!** SCAN THE QR CODE FOR A QUICK LINK

**See the world of concept cars with this video**

www.howitworksdaily.com

**DID YOU KNOW?** *The very first concept car, the Buick Y-Job, was unveiled in 1938, to gauge public interest for new designs*

# Toyota FV2

**The FV2 features some innovative technology**

**Height**
When the canopy is down, the FV2 is just 99cm (39in) tall. In driving mode, it measures 178cm (70in) tall.

**Interaction**
The vehicle can interact with the driver by suggesting alternative routes and even destinations to match the driver's mood.

**Canopy**
Acts as a lid when closed, or a windshield to protect the standing driver when raised.

**Steering**
The FV2 is controlled in a Segway-like manner, with the driver using weight transfer to control the vehicle.

**Wheels**
The FV2 comes with four wheels mounted in a 'diamond' layout.

**Illumination**
The outer shell can illuminate itself to match the perceived mood of its driver.

**Power**
Powered by an electric motor, though Toyota says the car can be adapted in future to suit alternative energy sources.

**Power**
The FV2 is currently powered by an electric motor, though Toyota says the car can be adapted in future to suit alternative energy sources.

## The statistics...

### *Toyota FV2*

**Available from:** Concept only

**Power source:** Electric

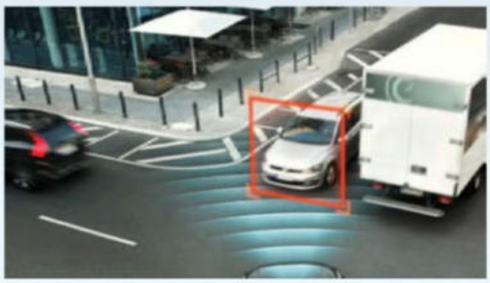
**Passengers:** None

**Connectivity:** Facial recognition detects mood to illuminate the vehicle.

**Safety:** Vehicle-to-vehicle communication.

# Safety at the driving wheel

**Volvo XC90's new safety tech is integrated into every level of driving**

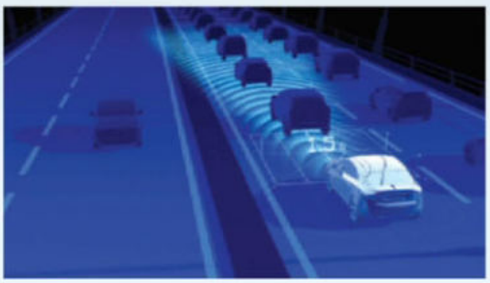


### AUTO BRAKE

The 2015 XC90 features automatic brake technology, which is applied when radars detect a collision is imminent. Volvo states the technology is particularly useful at busy city intersections. The car will automatically apply the brakes in order to avoid a collision, without the driver having to even initiate a stop.

### AIR SUSPENSION

The new XC90 will offer air suspension as an optional extra. This is electronically controlled, meaning the driver can adjust the settings from their seat. The air suspension has a choice of five settings, allowing all occupants of the vehicle to be transported in ultimate comfort.



### QUEUE ASSIST

Crawling along in traffic is an infuriating task for any driver, but Volvo's XC90 seeks to eliminate the monotony with its new Adaptive Cruise Control with Queue Assist. Using radars to slowly follow the vehicle in front, braking and steering is automatically controlled to keep directly behind the leading car.

"As cities are heavily traffic-laden, big, powerful engines are superfluous for such a slow-moving environment"

# CITY CARS

With the planet's cities continuing to swell, space is understandably at a premium – and that includes the roads. What's more, government legislation dictates cars must meet ever-lower emissions outputs in a bid to make Earth greener, with some cities such as London now implementing an added tax for driving cars in 'low-emission zones'. Vehicles will therefore have to adapt to a new life in the city of the future.

Fortunately, vehicle manufacturers are already well placed to meet these new demands for the city car, with the emerging breed of small, hybrid city cars marking the start of the transition.

Not only are these cars – such as the VW up! and Skoda Citigo – small and compact to save on space, they're also extremely environmentally friendly, meaning drivers won't be blighted by increasingly stringent inner-city emissions regulations.

As cities are heavily populated and often traffic-laden, big powerful engines in cars are superfluous for such a slow-moving environment. Therefore, these new city cars are fitted with small engines, such as the 1.0-litre unit fitted to the VW up!. The advantage of this is two-fold: first, the engines will be greener, meaning they will fall on the right side of tax and emissions legislation, plus they'll use less fuel (due to the small capacity of the engine), making these vehicles very cheap to run – another reason for the sector's popularity in the overall vehicle market.

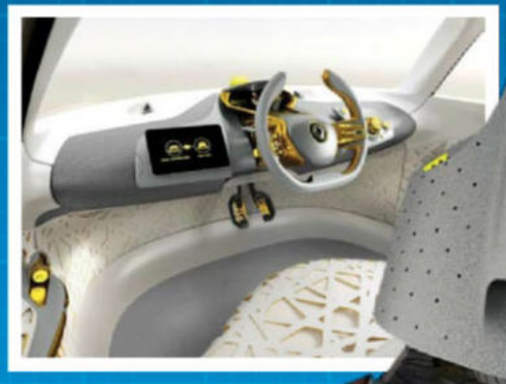
And if the Toyota FV2 concept car is anything to go by, these city cars are going to get even smaller in future.

**Renault Twizy**
This clever city car from Renault is a compact two-seater powered only by electricity, and is on the road now.

## The Renault KWID concept

**The French manufacturer's new concept is as wacky in design as it is in layout**

**Doors**
These open electrically, similar to the flashy items found on a Rolls Royce!



**Interior**
Inspired by a bird's nest in design, Renault says the white hue of the seats inspires connotations of lightness.

**Size**
The small nature of the KWID, with little overhang either side of each axle, makes it an ideal city vehicle.

**Dashboard**
The dashboard of the car acts as an integrated tablet device, allowing for first-hand control of the Flying Companion and other connectivity features.

# 5 TOP FACTS AUTONOMOUS CARS

**Google**
**1** Designed to be innovative and completely new, the Google self-driving car will be 100 per cent electric and a maximum speed of 40km/h (25mph).

**Tesla**
**2** A manufacturer that's always looking outside the box, the firm is pioneering a whole new 'autopilot' feature for a 2019 release on its Model S brand.

**BMW**
**3** Likely to be introduced to their 2 and 6-series lines, BMW's autonomous cars will have 360-degree sensors to map out their surroundings.

**Audi**
**4** Audi are focusing their efforts on autonomy in low speed traffic so to make rush hour more bearable, grab an Audi in a couple of years time.

**Toyota**
**5** Using Automated Highway Driving Assist technology, future Toyotas will have plenty of new features such as lane trace and cruise control.

**DID YOU KNOW?** *A group of nine European manufacturers are testing energy-storing body panels for increased electric-car range*

**'Flying Companion'**
The KWID comes with a remote-controlled drone that can be sent into the air to monitor traffic or take pictures.

**Engine**
The KWID is powered by a turbocharged 1.2-litre engine, keeping emissions down but power up.

**Seating**
This five-seater breaks convention by having a three-person bench in front of two seats.

**Driver position**
The steering wheel is mounted in the middle of the dashboard, so the driver sits in the middle of the front bench instead.

**Alternative energy**
The KWID can switch to pure electric energy if the technology becomes mainstream, with space set aside to add batteries to the car in future.

## The statistics...

### *Renault KWID*

**Available from:** Concept only

**Power source:** Turbocharged gasoline engine; can adapt to electric power in future.

**Passengers:** Five

**Connectivity:** 'Flying Companion' drone controlled from dash-mounted tablet.

**Safety:** Central-mounted steering wheel, so neither left nor right-hand drive

# HOW HYBRIDS WORK


ELECTRIC MOTOR IN USE THROUGHOUT
PETROL ENGINE USED
BATTERY POWER USED
BATTERY RECHARGING

"The carrier will have the capacity to accommodate up to 40 aircraft, including the F35 Lightning II"

# HMS Queen Elizabeth

## Take a look inside the Royal Navy's biggest-ever vessel

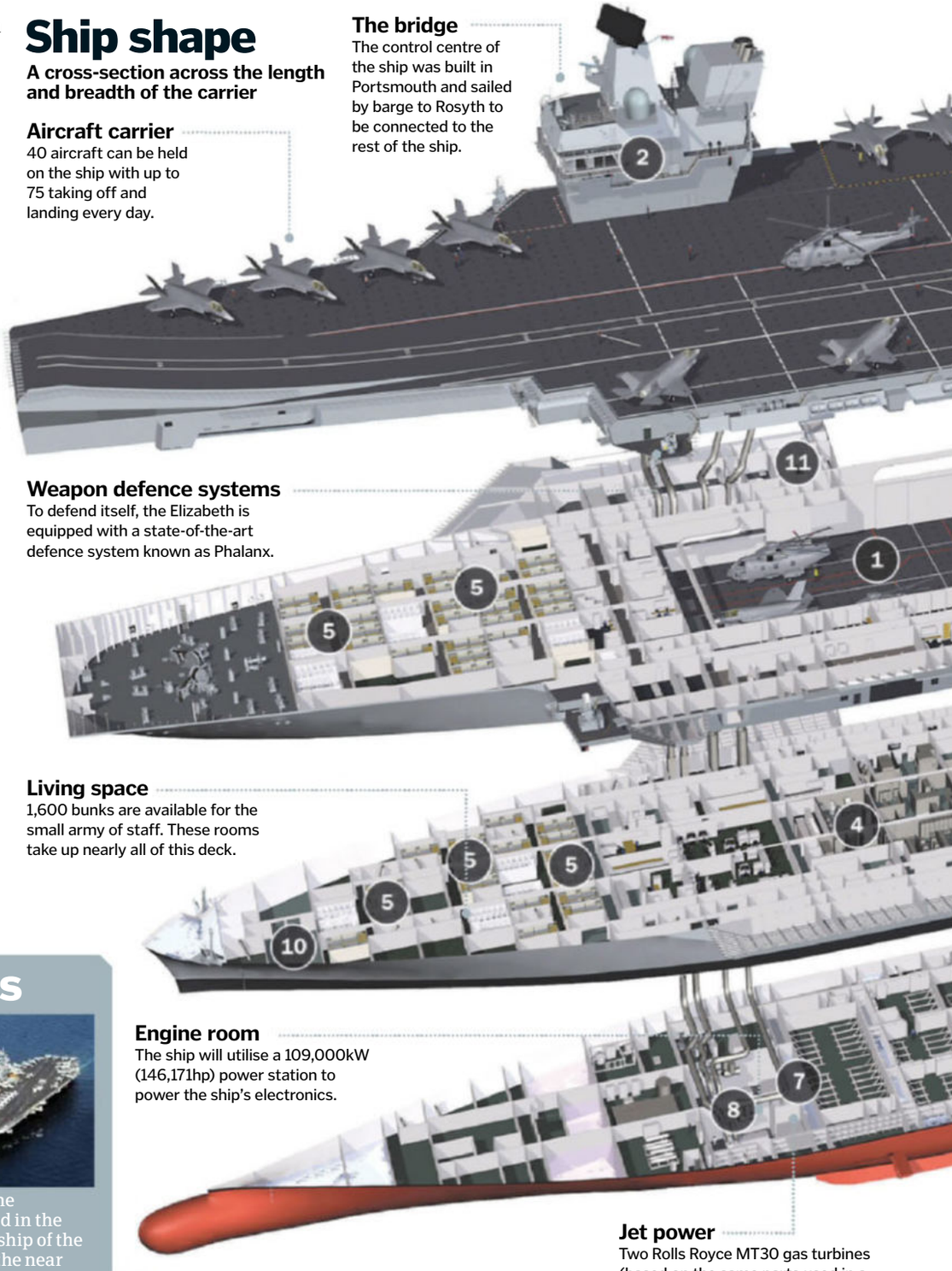
Taller than the Niagara Falls with room for four jumbo jets, the HMS Queen Elizabeth is a true naval goliath. The construction called for six shipyards and 10,000 workers, and it's kitted out with state of the art facilities and technology. As well as a cinema and fitness suite for the 1,600-strong crew to unwind in, the carrier will have the capacity to accommodate up to 40 aircraft, including the world's most advanced stealth bomber family, the F35 Lightning II.

In a combat situation it can call on a set of 20mm guns, which are part of an automated Phalanx CIWS (close-in weapon system) that will protect the craft from missiles. If flight is preferred to fight, the two Rolls-Royce MT30 gas turbines and four diesel generator sets give the ship a power of 109,000 kilowatts (146,171 horsepower). That's enough to power a small city! The engines givesthe vessel a top speed of 25 knots (46 kilometres / 29 miles per hour) and a range of 16,000 kilometres (10,000 miles).

Incredibly heavy ships – like the Elizabeth – can still float because when the boat is pushing down, the water pushes up. As long as the vessel is not as heavy as the water it has displaced, it will float – a principle called buoyancy. This particular ship will begin sea trials in the summer of 2016. To achieve this, it will have to will have to disembark from its current location in Rosyth Dockyard in Scotland by going under the Forth Bridge. This can only be done at low tide as the HMS Queen Elizabeth is simply too much of a giant to clear it at high tide!

## Ship shape

**A cross-section across the length and breadth of the carrier**




**The bridge**
The control centre of the ship was built in Portsmouth and sailed by barge to Rosyth to be connected to the rest of the ship.

**Aircraft carrier**
40 aircraft can be held on the ship with up to 75 taking off and landing every day.

**Weapon defence systems**
To defend itself, the Elizabeth is equipped with a state-of-the-art defence system known as Phalanx.

**Living space**
1,600 bunks are available for the small army of staff. These rooms take up nearly all of this deck.

**Engine room**
The ship will utilise a 109,000kW (146,171hp) power station to power the ship's electronics.

**Jet power**
Two Rolls Royce MT30 gas turbines (based on the same parts used in a Boeing 777) power the engine along with four diesel engines.

## The Invincible class

Before the Queen Elizabeth class was even a twinkle in the Royal Navy's eye, the Invincible class ruled the waves. The first of this class of light aircraft carrier was the HMS Invincible itself, which was first commissioned in 1980. Followed by the HMS Illustrious and HMS Ark Royal, the vessels served during the Falklands War and the Bosnian War and assisted in the 2003 invasion of Iraq. The Illustrious is the only ship of the class still in service but it is due to be retired in the near future. It will possibly be turned into a tourist attraction in Hull, hosting events and exhibitions on the River Humber.

# AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

## The HMS Queen Elizabeth in numbers

www.howitworksdaily.com


**DID YOU KNOW?** *The foghorn is 162 decibels and can be heard from more than 3.2km (2mi) away*

### Flight control
This tower regulates air traffic and controls the ship's radar systems.

### Aircraft lift and hangar
Several aircraft will be placed below deck for extra space and will be raised up using a special lift when required.

### Propulsion
The ship's two propellers are 7m (23ft) in diameter and are equipped with enough power to run 1,000 cars or 50 high-speed trains!

### Medical area
The ship contains various medical areas as well as a hospital to treat staff on long journeys.

## The statistics...

### HMS Queen Elizabeth

**Cost:** £6.2 billion ($10.3 billion)
**Weight:** 65,000 tons
**Length:** 280m (919ft)
**Height:** 56m (184ft)
**Crew:** 1,600

## The original HMS Queen Elizabeth

In the early-20th century, dreadnoughts were the battleships of choice. The original Queen Elizabeth class was a series of five super-dreadnoughts that served the Royal Navy through both world wars. Six were designed but HMS Agincourt was cancelled due to the outbreak of World War I. The vessels all made it through both world wars except HMS Barham, which was sunk by a German submarine in 1941. By this time the armour of the vessels had become obsolete and could not protect against torpedo fire. They were deployed all over the world before being effectively replaced by the Revenge class of battleships and were scrapped in the late-1940s.

The first HMS Queen Elizabeth was the flagship of the Royal Navy, serving for 34 years

**12,000**
CANS OF BAKED BEANS ON BOARD, ENOUGH TO FILL 38 BATHTUBS

**64,800**
EGGS ON BOARD ENOUGH FOR 21,600 OMELETTES

**66,000**
SAUSAGES IN THE SHIP'S STORES – THAT'S 6.5KM (4MI) WORTH

**1,000**
LOAVES OF BREAD PRODUCED A DAY BY THE SHIP'S ONBOARD BAKERY

"The material and shape encourages upward movement, so all aeroplanes need to do is provide enough thrust"

# Aeroplane wings

## How do planes defy gravity so easily?

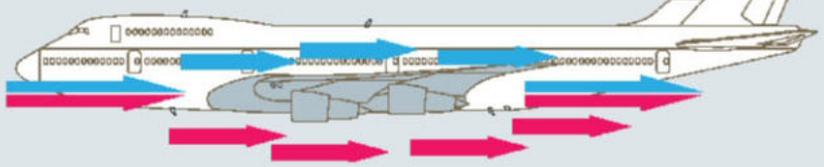
Considering the sheer size and weight of an aeroplane, it's a wonder they get off the ground at all. The secret lies in the shape of their wings. As they are curved on top, the air moves more quickly over the wing than under it. This reduces the air pressure above the wing, meaning that the plane is more inclined to move up toward the area of lower pressure.

Wings tend to be made of aluminium, as this is both strong and light. The combination of material and shape encourages upward movement, so all aeroplanes need to do is provide enough thrust – either from a propeller or jet engine – so the airflow can produce enough lift for the plane to fly.

### Under pressure

**Low pressure**
Air flows faster over the curve of the wing, making the pressure above the wing lower than underneath it.

**High pressure**
The slower-moving air underneath the wing helps lift the plane into the area of lower pressure.



# Cool your engines

## How a typical engine cooling system works on a car

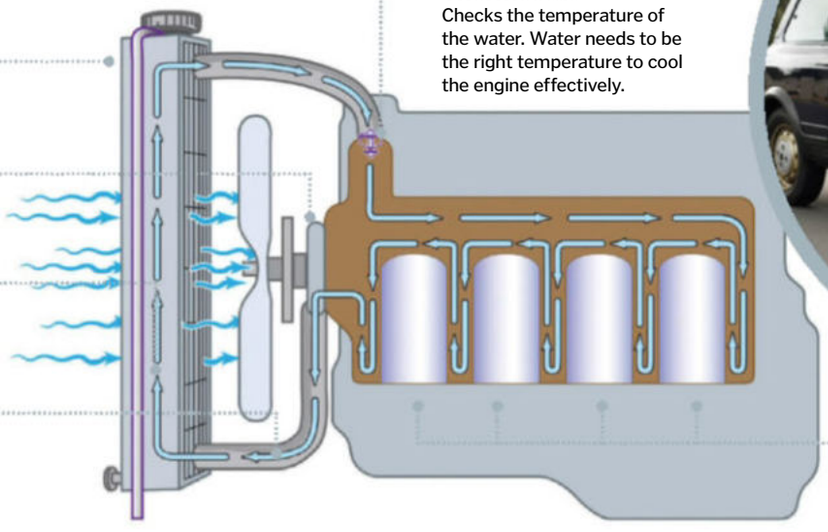
If a car's cooling system breaks down, the engine will be overheated and damaged as a result

**Radiator**
If the water is too hot, the radiator cools the fluid by releasing heat into the air.

**Pump**
If the water is cool enough, the pump will send it into the engine.

**Water flow**
The heated water leaves the engine and goes back up the cooling system, where it gets chilled by the radiator fan.

**Water levels**
If there isn't enough water in the system, the engine can't cool down quickly enough, so the engine is liable to overheat.



**Thermostat**
Checks the temperature of the water. Water needs to be the right temperature to cool the engine effectively.

**Cylinders**
The cylinders in the engine get very hot so the circulating water draws heat away from the system.

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IOP Institute of Physics

Department for Education

*Conditions apply. Visit education.gov.uk/teachconditions

# FOOD & YOUR BODY

## Join us as we unravel all nine metres of your digestive system

The digestive tract is a long, muscular tube that runs the entire length of your body. It is separated into five distinct sections, each with its own particular and specialised function.

Digestion begins in the mouth. As you chew your food, saliva is released, providing a slippery lubricant and kick-starting the break down of carbohydrates with an enzyme known as amylase. Touch receptors in your mouth tell you when it is time to swallow, and as your tongue comes upward, the food is pushed to the back of your throat.

As you swallow, you pass control of digestion over to your automatic motor functions. A flap of skin called the epiglottis folds down to cover the voice box, and the entrance to the lungs, and then a wave pushes the mouthful all the way down the oesophagus. When the food reaches your stomach, it passes through a ring of muscle known as the cardiac sphincter, which prevents it from coming back out the way it came in.

The inside of the stomach is a hostile environment, where the cells lining the walls pump out hydrochloric acid and protein-digesting enzymes. The presence of food triggers stretch receptors in the stomach lining, which in turn trigger a series of rhythmic contractions. These churn the stomach contents, mixing in the acid and enzymes, grinding down the food.

At the bottom of the stomach there is a second ring of muscle called the pyloric sphincter, which acts as a gatekeeper to the small intestine. The sphincter prevents anything larger than about two centimetres (0.8 inches) in diameter passing through, returning it to the body of the stomach until it has

1. COMMON

**Shellfish**
Shellfish allergies tend to develop during adulthood. Foods to avoid include barnacles, crabs, shrimps, lobsters, crawfish and krill.

2. MORE COMMON

**Milk**
Children under the age of three are the most likely to develop an allergy to milk, but they usually outgrow it by the time they reach adulthood.

3. MOST COMMON

**Peanuts**
By far the most common food allergy is peanuts. In the UK, as many as one in 50 children are sensitive.

**DID YOU KNOW?** *Biological washing powder uses digestive enzymes to break down the stains on dirty laundry*

been ground down further. This ensures that by the time it reaches the small intestine, your food is a runny, slightly lumpy paste, and is ready for the next stage of digestion.

The small intestine is the site of chemical digestion. Here, the pancreas adds digestive enzymes, and the liver adds a generous squirt of alkaline bile, delivered via the gall bladder. This bile not only neutralises the burning stomach acid, it also acts a little like washing-up liquid on dirty dinner dishes, helping to separate the food particles and forcing fats to disperse into tiny bubbles.

Muscles in the small intestine continue to squeeze and mix the contents together, allowing the enzymes to get to work inside the paste. As the nutrients are released, they are then absorbed over the walls of the intestine and into the bloodstream.

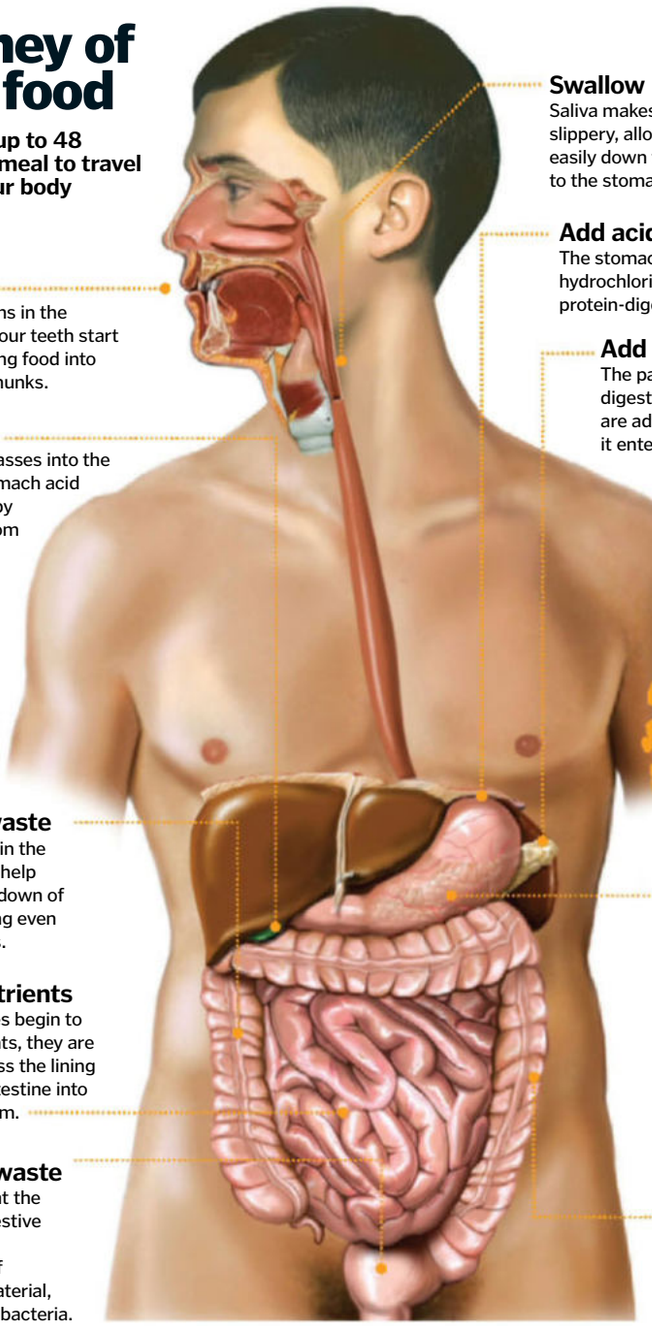
To ensure that everything keeps moving through the system, every five to ten minutes a wave of muscle contractions begins at the stomach and travels all the way down the intestines. Known as the migrating motor complex (MMC), this wave squeezes the digestive system like a tube of toothpaste, urging its contents further toward the colon.

As the food progresses through the small intestine, more and more of the nutrients are released by enzyme activity, and by the time it gets to the large intestine, most of the useful material has been absorbed into the bloodstream. However, the digestive process is not over, and here, bacteria help to break down even more of the undigested food.

The large intestine also absorbs most of the remaining water, leaving behind a combination of undigested material, dead cells and bacteria. When the waste has completed its journey through the large intestine it goes to the rectum for storage until there is a convenient time to get rid of it.

# Journey of your food

**It can take up to 48 hours for a meal to travel through your body**



**Swallow**
Saliva makes each mouthful slippery, allowing it to slide easily down the oesophagus to the stomach.

**Chew**
Digestion begins in the mouth, where our teeth start work on grinding food into manageable chunks.

**Add acid and enzymes**
The stomach produces hydrochloric acid, and protein-digesting enzymes.

**Add more enzymes**
The pancreas produces digestive enzymes, which are added to the mixture as it enters the small intestine.

**Add bile**
As the liquid passes into the intestines, stomach acid is neutralised by alkaline bile from the liver.

**7 metres**
LENGTH OF THE SMALL INTESTINE

**Ferment waste**
Bacteria living in the large intestine help with the breakdown of waste, releasing even more nutrients.

**Churn**
The muscles of the stomach rhythmically churn its contents, mechanically breaking the food down into a lumpy paste.

**Absorb nutrients**
As the enzymes begin to release nutrients, they are absorbed across the lining of the small intestine into the bloodstream.

**Get rid of waste**
All that is left at the end of the digestive process is a combination of indigestible material, dead cells and bacteria.

**Remove water**
The large intestine absorbs excess water from the food as it passes through.

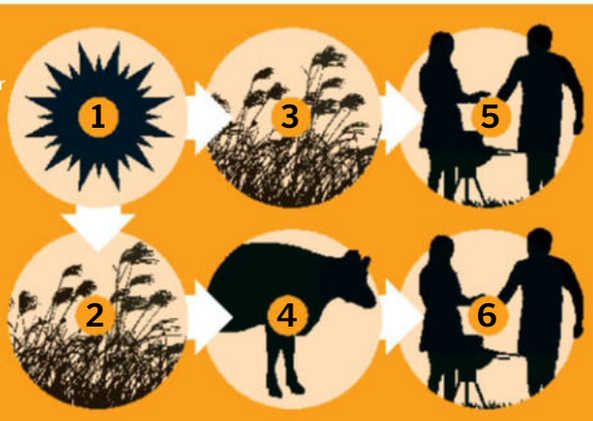
# Food chain

Energy from the Sun is converted into to chemical energy by photosynthetic organisms like plants. The plants use the energy to build biological materials from nutrients in the air and soil. Herbivores then consume the plants, releasing some of the energy, and using the components to build their own bodies. Carnivores then eat the herbivores. When plants and animals die, decomposers break their bodies down, returning nutrients to the ground for reuse, and the cycle begins again.

**1 The Sun**
On average, every minute the Sun delivers 2kcal of energy for every $cm^2$ ($0.2in^2$) of Earth.

**2 Inefficient conversion**
Less than five per cent of the available energy from the Sun is converted into chemical energy by plants.

**3 Producer**
Plants use the energy from the Sun to combine $CO^2$ and water, producing chemical energy in the form of sugars.




**4 Herbivore**
Herbivores can digest plant material, but the process is difficult, and they can only extract around ten per cent of the energy.

**5 Energy loss**
At every step up in the food chain, some of the energy is lost, mostly as heat.

**6 Carnivore**
Carnivores get easy energy by digesting the tissues of other animals.

"Scientists have found that these olfactory receptors can detect as many as 1 trillion different odours"

# Sense of taste

**Taste tells us whether our food is safe to eat, but smell gives it flavour**

The human tongue is able to detect five different tastes: sweet, sour, salty, bitter and umami (savoury), providing us with a quick way to distinguish between different types of food. Sweet foods contain sugar and are a good source of energy. Salty foods provide sodium, which is vital for nerve function, but deadly in high quantities. Bitter foods might contain poison.

Babies are born with a natural preference for sweet food and a dislike of bitter, providing a biological safeguard that encourages them to eat safe, high-calorie food. However, nutrition is not that simple. Many vegetables are bitter but not poisonous and so learning to like them comes with experience.

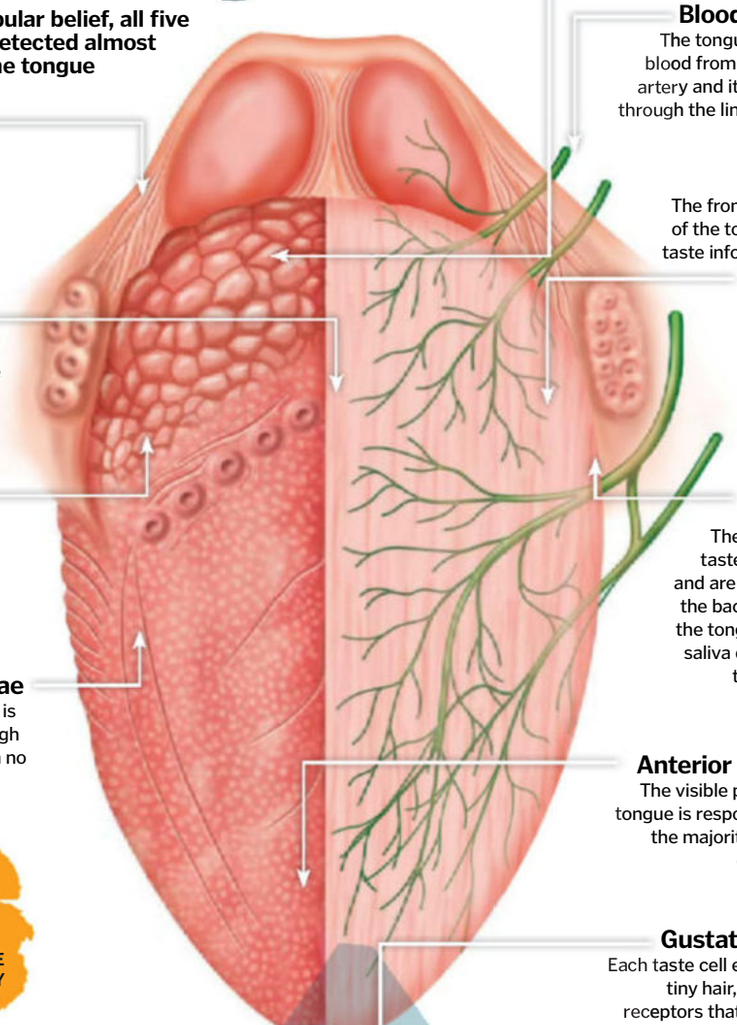
The degree to which we can detect different tastes varies, and appears to be dictated by our individual anatomy. The population can be broadly divided into three categories based on the number of taste buds on their tongue. Those with the fewest are known as 'non-tasters', those with an average number are known as 'tasters', and those with many more taste buds than the rest if the population are 'supertasters.' Supertasters are especially sensitive to taste and will react much more strongly than the rest of the population. As a result, they tend to really dislike bitter foods like green vegetables and coffee, and often shy away from rich desserts and sugary sweets.

Though these anatomical differences can explain some of our food preferences, most our individual likes and dislikes are not down to taste, but to flavour; the combination of taste and smell. The act of chewing food releases chemicals known as volatiles, which evaporate rapidly. As we swallow, some of the air inside the mouth is forced up toward the nose, carrying these volatiles with it. Here, they bind to receptors on olfactory cells, triggering sensory messages to the brain.

Recently, scientists have found that these olfactory receptors can detect as many as 1 trillion different odours. Taste and smell are strongly linked to emotion and memory, and as a result, experience is a powerful decider in the development of our likes and dislikes.

## Anatomy of a human tongue

**Contrary to popular belief, all five tastes can be detected almost anywhere on the tongue**



**Circumvallate papillae**
These large bumps are found at the back of the tongue, each surrounded by a dip that collects saliva.

**Blood supply**
The tongue receives blood from the lingual artery and it drains out through the lingual veins.

**Nerves**
The front and back of the tongue send taste information to the brain.

**Muscle**
There are eight muscles in the tongue that alter its shape and change its position.

**Posterior tongue**
About a third of the tongue is hidden right at the back of the mouth.

**Papillae**
The tongue is covered in tiny bumps, but not all of them contain taste buds.

**Foliate papillae**
These contain taste receptors and are located on the back edges of the tongue, where saliva drips down the cheeks.

**Filiform papillae**
Most of the tongue is covered in thin, rough bumps that contain no taste receptors.

**Anterior tongue**
The visible part of the tongue is responsible for the majority of taste detection.

**10**
**TASTE CELLS ARE REPLACED EVERY TEN DAYS**

## What is a taste bud?

**Gustatory hair**
Each taste cell ends with a tiny hair, covered in receptors that allow it to detect chemicals dissolved in the saliva.

**Pore**
A tiny gap at the top of the taste bud allows saliva to touch the taste cells.

**Basal cell**
Ageing or damaged taste cells are replaced by the basal cells waiting underneath.

**Support cell**
The taste cells are surrounded by an envelope of non-tasting support cells.

**Sensory cell**
Each cell is sensitive to one of the five tastes, but all types are found together in a single taste bud.

**Synapse**
Taste cells do not transmit the signals to the brain themselves, instead passing the message over to a nerve cell.

**Nerve**
Messages are relayed to the brain via a nerve that exits at the bottom of the taste bud.

## THE STATS
THE JOURNEY OF FOOD

**9m** LENGTH OF DIGESTIVE SYSTEM

**1-3 HOURS** TIME IN STOMACH

**40 hours** TIME IN LARGE INTESTINE

DAILY INTAKE **1.8kg**

DAILY OUTPUT **350g**

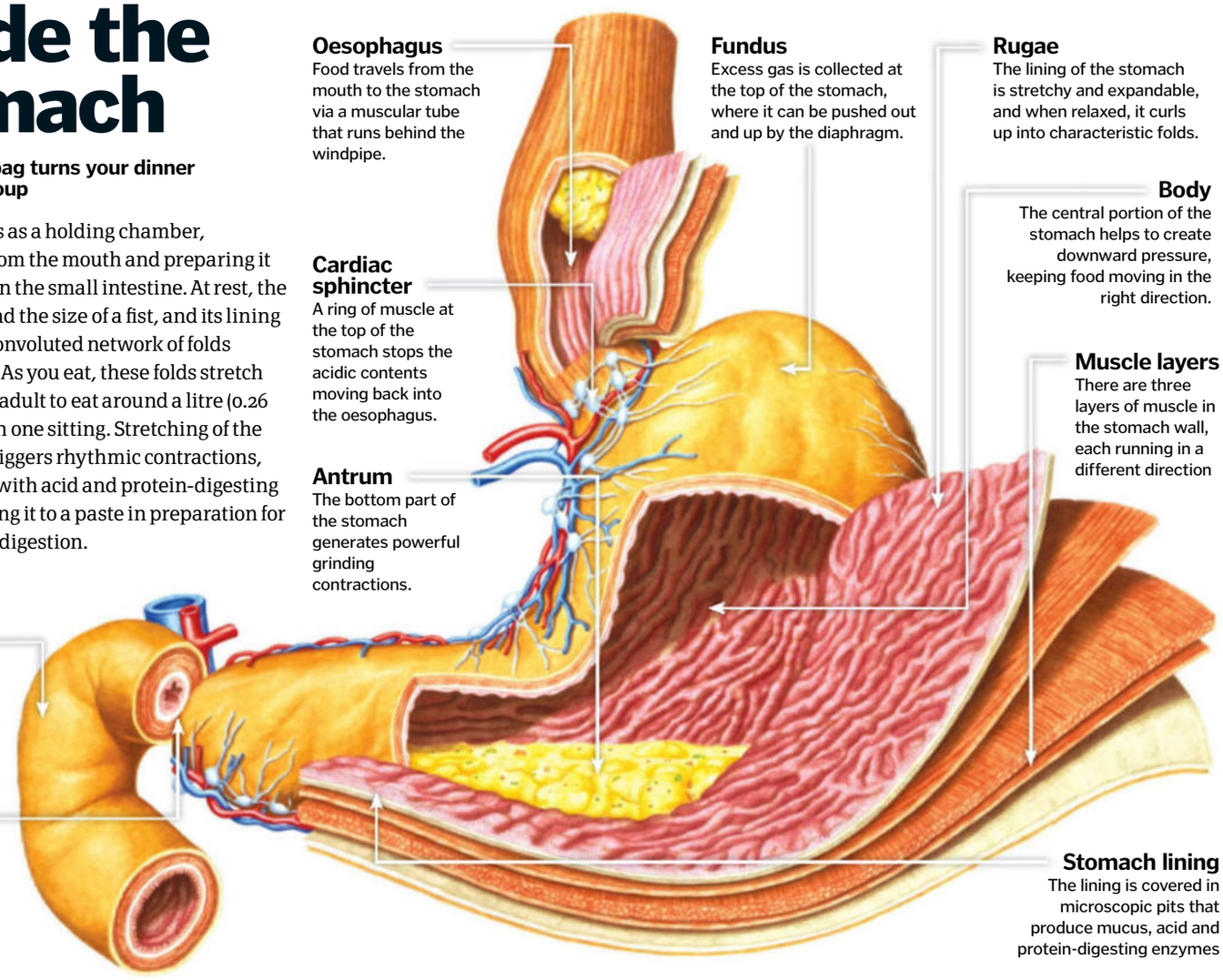
AVERAGE DIGESTION TIME **53 hours**

**DID YOU KNOW?** *Stomach ulcers were long thought to be caused by stress, but it's now known the culprit is a bacterial infection*

# Inside the stomach

**This muscular bag turns your dinner into an acidic soup**

The stomach acts as a holding chamber, receiving food from the mouth and preparing it to be processed in the small intestine. At rest, the stomach is around the size of a fist, and its lining is curled into a convoluted network of folds known as rugae. As you eat, these folds stretch out, allowing an adult to eat around a litre (0.26 gallons) of food in one sitting. Stretching of the stomach walls triggers rhythmic contractions, mixing the food with acid and protein-digesting enzymes, grinding it to a paste in preparation for the next stage of digestion.



**Oesophagus**
Food travels from the mouth to the stomach via a muscular tube that runs behind the windpipe.

**Fundus**
Excess gas is collected at the top of the stomach, where it can be pushed out and up by the diaphragm.

**Rugae**
The lining of the stomach is stretchy and expandable, and when relaxed, it curls up into characteristic folds.

**Body**
The central portion of the stomach helps to create downward pressure, keeping food moving in the right direction.

**Cardiac sphincter**
A ring of muscle at the top of the stomach stops the acidic contents moving back into the oesophagus.

**Muscle layers**
There are three layers of muscle in the stomach wall, each running in a different direction

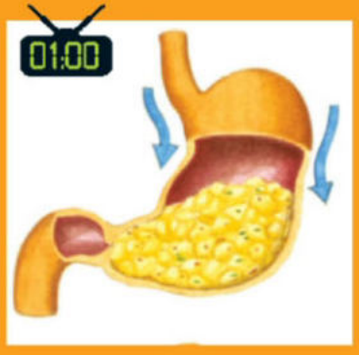
**Antrum**
The bottom part of the stomach generates powerful grinding contractions.

**Duodenum**
The stomach empties its contents into the first section of the small intestine.

**Pyloric sphincter**
A ring of muscle at the base of the stomach prevents the contents from leaking out before they are ready.

**Stomach lining**
The lining is covered in microscopic pits that produce mucus, acid and protein-digesting enzymes

## How long does it take to digest food?




The sight, smell and even the thought of food begin to prepare the stomach for a meal, so by the time the swallowed mouthfuls start to arrive, it is already producing more acid.


Stretching and irritation of the stomach trigger it to turn up acid and enzyme production and to start churning. For the first 20 to 30 minutes after eating a meal, no food is allowed to leave.


To stop the stomach emptying too quickly, protein and fat are monitored in the first part of the small intestine. If too much food comes through, the intestine sends signals to slow the stomach down.

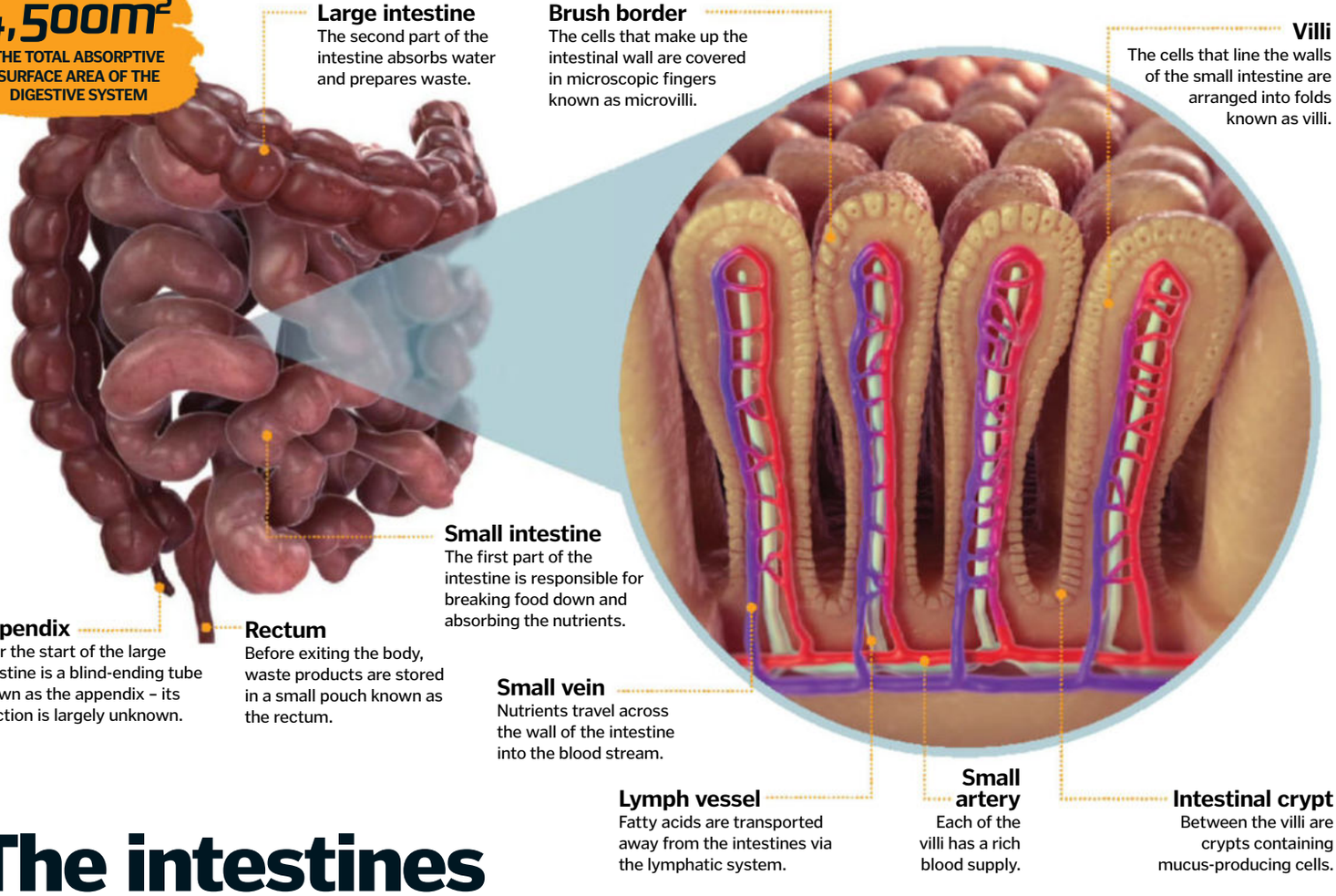
# Chewing the fat

**Fat has a bad reputation, but the truth is, your body needs it**

Every single cell in your body is surrounded by a membrane made of fats; it insulates your nerves and it provides a valuable energy reserve. Eating fat also provides a number of vitamins and essential fatty acids the body can't make on its own. Saturated fats (the solid fats found in meat and dairy) and trans fats (found in hydrogenated vegetable oil and many processed foods) have shown to raise cholesterol, which can lead to circulatory problems, but unsaturated fats (the liquid fats found in plants and fish) can have the opposite effect, and are considered good for your health.

"The enzymes act like molecular scissors, breaking proteins, carbohydrates and fats down"

**4,500m²**
THE TOTAL ABSORPTIVE SURFACE AREA OF THE DIGESTIVE SYSTEM




# The intestines

**After leaving the stomach, food must pass through over 7m (23ft) of intestines**

The stomach contents enter the intestine gradually, allowing time for the liquid food to be processed. First the acid is neutralised by bile, provided by the liver, and then digestive enzymes are added by the pancreas. The enzymes act like molecular scissors, breaking proteins, carbohydrates and fats down into building blocks small enough to be carried over the wall of the small intestine. The remaining undigested material passes into the large intestine, which absorbs water, leaving behind solid waste that can then be passed out of the body.

## Living with bacteria

Bacteria are often portrayed as the 'bad guys' of the body, but the proportion that cause food poisoning is surprisingly small. In fact, bacteria start to move into your digestive system from the moment you are born, and a healthy adult has around 300 to 500 different resident species living in their large intestine at any one time.

The upper parts of the digestive system are hostile to microorganisms; the stomach is highly acidic and the small intestine is filled with digestive enzymes, but the large intestine provides the perfect environment for sustaining a microscopic world.

By the time food reaches this point, our digestive enzymes have done their work and most of the nutrients have been absorbed, but bacteria have a different set of enzymes. They are able to break indigestible material down even further, allowing us to absorb even more nutrients, mainly in the form of fatty acids.

The presence of these helpful bacteria also means there is little space or resources left for dangerous pathogens, helping to keep infections at bay.

The gut and its resident bacteria are in constant communication, picking up on chemical signals released into the environment. These signals can have far-reaching effects, and the types of bacteria present in your intestines have been shown to influence other organs, including the brain.

## 5 TOP FACTS
### FOOD MYTHS DEBUNKED

**1 Eight glasses of water**
Drinking plenty of water is beneficial for our health, but there is nothing special about drinking eight glasses. Drinking when you feel thirsty is usually more than enough.

**2 Vitamin C stops colds**
In trials involving over 11,000 people, it has been shown that vitamin C does not prevent or cure colds. However, washing hands regularly is effective at preventing transmission.

**3 Carrot night vision**
Carrots contain vitamin A, vital for eye health, but the idea that they help you see in the dark is a lie from WWII to keep radar technology secret from the Germans.

**4 Celery's minus-calories**
It is a popular fact among dieters that eating celery burns more calories than it provides. Although possible in theory, no foods have been found to have this effect.

**5 Chocolate causes acne**
Actually, this one might be true. New research is increasingly suggesting that diet does have an impact on acne and that saturated fats and sugars might be to blame.

**DID YOU KNOW?** *The human mouth produces 1-2 litres of saliva every day*

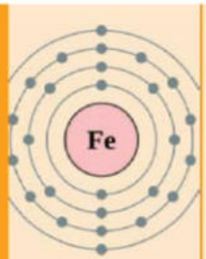
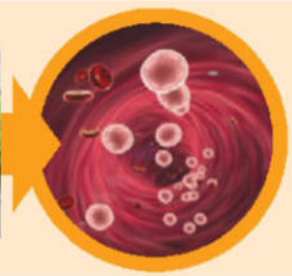
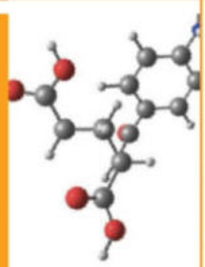
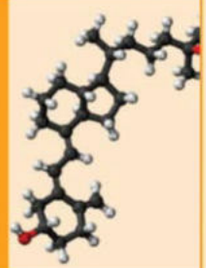
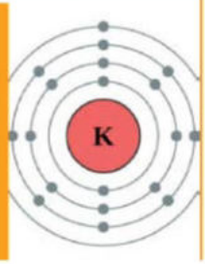
The first part of the digestive system prepares the food for the next stage, ensuring it is broken into a fine paste, mixed to form a homogenous fluid, and shocked with acid to limit the potential for dangerous infection. However, it is not until food reaches the small intestine that the microscopic breakdown and absorption of nutrients really begins.

At the start of the small intestine, the liver injects alkaline bile into the acidic liquid food, neutralising its pH and preparing it for the introduction of digestive enzymes.

Bile also helps to emulsify fats. Fats are not water soluble, so they tend to clump together in large globules to hide from and avoid the surrounding water, but bile acts a little like washing-up liquid, separating the fats out into smaller blobs.

Now that the food is nicely mixed and separated, the enzymes can really get to work. The pancreas produces a cocktail of three kinds of enzyme, each used to break down a different type of molecule. Proteases clip amino acids from proteins, lipases break fats down into fatty acids and glycerol, and carbohydrases turn long chains of carbohydrate into sugars. These small blocks can be absorbed into the bloodstream, where they are distributed around the body, used to build our own biological molecules, or broken down and burnt for energy. The body requires different quantities of each of the nutrients, and can sometimes convert one into another if supplies are running low. However, there are a number of nutrients that cannot be synthesised by the body at all or in high enough quantities, and these must be obtained directly from the diet. These essential nutrients include some types of amino acids, fatty acids like omega-3 and omega-6, and all of the vitamins and minerals needed.

Vitamins and minerals are organic and inorganic compounds required by the body in small amounts for various different functions. Some of these, like calcium, make up vital structural components of our bodies, while others, like vitamin C, are involved in biochemical reactions.

| MOLECULE / VITAMIN | FOOD YOU'LL FIND IT IN | WHAT THE BODY USES IT FOR |
|---|---|---|
| IRON |   | IRON-RICH FOOD  Egg yolks  Red meat  Spinach  | Iron is a key component of haemoglobin, the red pigment that carries oxygen in our blood. Without it, oxygen cannot be transported effectively, resulting in iron-deficiency anaemia. This is most often caused by blood loss, so as a result, women are much more likely to be deficient of iron than men. |
| FOLIC ACID |  | GREEN LEAFY VEGETABLES  Cauliflower  Broccoli  Brussels sprouts  | Folic acid is essential for the synthesis of DNA and without it the production of red blood cells starts to slow down. It is also extremely important in the formation of the central nervous system, and during the first 12 weeks of pregnancy, folic acid supplementation is recommended to pregnant women. |
| VITAMIN D |  | OIL FISH  Salmon  Tuna  Caviar  | Vitamin D is involved in bone formation in the body, so deficiency of vitamin D in children can result in bone deformity. Luckily, this vitamin is easy to obtain. Not only can vitamin D be found in oily fish, eggs and dairy products, but our bodies can also make it themselves using sunlight. |
| POTASSIUM |   | FRUITS  Dried apricots  Avocados  Bananas  | Cells use a combination of potassium and sodium to maintain their internal electrical balance. Potassium is vital to ensure muscles are able to contract properly and nerves are able to transmit their messages. It is easily obtained in the diet and deficiency is incredibly rare unless there is damage to the kidneys. |

"Cravings are slightly different. These are generated not in the stomach, but in the brain"

Hunger is one of the body's most basic and fundamental sensations, and it originates in the stomach. When the stomach is empty, it begins to produce a hormone known as ghrelin. This then travels to a region of the brain known as the hypothalamus.

The hypothalamus is responsible for maintaining a constant, optimum state; keeping the body at a set temperature, regulating hormones and monitoring hydration. The arrival of ghrelin is a signal that energy levels might be about to dip, so it triggers the production of a second hormone, neuropeptide Y. This hormone promotes eating.

The cue to stop eating is much more subtle. The stomach has stretch receptors, and will signal to the brain that it is full. But what happens if it is empty, but there is already enough energy stored in the system? Fat stores produce a hormone known as leptin, which tells the brain exactly how much energy the body has in reserve. When leptin levels are high, the hypothalamus makes hormones that suppress appetite.

The trouble is that with high levels of fat, we can become resistant to the leptin message, similar to insulin resistance in type-II diabetes. If the brain does not know there is enough fat, we just keep eating.

Cravings are slightly different. These are generated not in the stomach, but in the brain. There are three main areas of the brain implicated in food cravings, the hippocampus, the insula and the caudate.

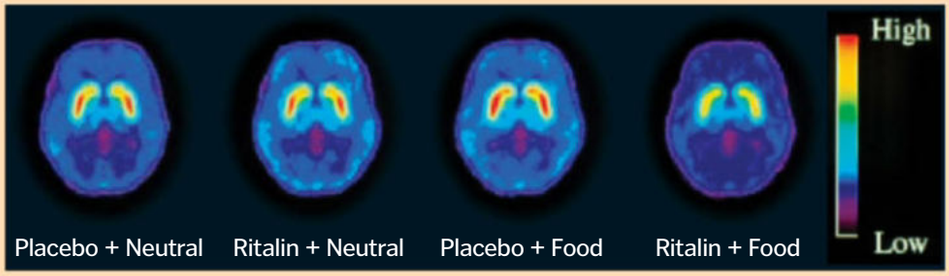
Humans have been programmed through evolution to enjoy fatty and sugary foods; eating them ensures we have enough energy to survive. The hippocampus is involved in gathering sensory information, and processing it for long-term memory storage, and with food cravings, these memories become associated with activation of the brain's reward circuitry. The more we enjoy eating a food, the more likely we are to crave it.

Mental images are thought to play an important role in food cravings and picturing food makes it much harder to resist. But thinking about other visual images can help to curb the cravings and distract your brain.

Digestion happens subconsciously, but you do have a manual override, and what your brain thinks it wants isn't always what it needs.

## Food addiction

Research into food addiction is relatively new and the results are hotly debated, but there is increasing evidence that food can elicit some of the same brain responses as addictive substances like cocaine. In overweight people, overeating can become a compulsion that is difficult to control, and has been shown to activate the same reward pathway that lights up when addictive drugs are ingested. In alcoholics, cocaine addicts and heroin addicts, the number of dopamine receptors in the reward pathway is lower than in the rest of the population and the same thing is found in obesity. It is thought that people with fewer dopamine receptors might need to over-stimulate their brains to experience the same rewards as normal people, and therefore turn to alcohol, drugs, or perhaps even food.




# Food and the brain

**Why do we crave these foods?**

### Comfort food

When we are feeling stressed or sad, many people turn to comfort foods such as mashed potatoes, beans on toast or macaroni cheese. Carbohydrates not only make us feel warm and full, they actually increase levels of serotonin, sometimes known as the happy hormone.

### Sweets

Sugary foods are craved for many reasons, the simplest of which is that your body needs an energy boost. However, eating sugar is just a temporary fix, and as the sugar is rapidly cleared from the blood, the craving will quickly return.

### Salty snacks

Animals have what is known as a 'salt appetite', similar to thirst, which drives them to seek out salt when they are running low. However, there is little evidence for an equivalent trait in humans. Men are more likely to crave salty foods than women, though.

## How long does chewing gum stay in your system?

**A** Seven years **B** A day **C** Forever

**Answer:**
It is true that chewing gum cannot be digested, but as long as it is a small piece – less than 2cm (0.8in) in diameter – there is no reason it should get stuck, and it should pass out normally within a day or two.

**DID YOU KNOW?** *The digestive system has its own dedicated nervous system, known as the enteric nervous system*

# CHEMISTRY OF FOOD

**TAKE A LOOK AT THE CHEMICALS BEHIND SOME OF OUR FAVOURITE FOODS AND DRINKS**

## Tea

In England, drinking tea is a national pastime. The main chemicals in tea are known as polyphenols, and each cup contains around 200 milligrams (0.007 ounces). The polyphenols are large molecules made up of smaller building blocks, which are known as catechins. When these catechins react with oxygen, they make two types of chemical; theaflavins, which make the orange-brown colour of tea, and thearubigins, which are thought to contribute to the taste. The different amounts of the chemicals present in the tea are very dependent on the life of the plants and the processing of the leaves.

## Chocolate

Chocolate is one of the foods most commonly associated with happiness, particularly the hormone serotonin. The chocolate itself does contain the precursor to serotonin, an amino acid known as tryptophan, but this is also found in many other foods, including meat. Chocolate also contains phenylethylamine, a molecule chemically similar to amphetamine, but it is broken down in the digestive system, and does not reach the brain intact. The feel-good factor of chocolate is more likely to be down to its fat and sugar content, and a property known as mouthfeel. Chocolate is among the only foods that melts at close to body temperature.

**30 CM**
**THE LENGTH OF AN AVERAGE STOMACH AFTER A MEAL**

## Coffee

Coffee contains over 1,000 different aroma compounds, responsible for its unmistakable smell. Around 12 per cent of the green coffee bean is made up of a set of chemicals known as chlorogenic acids, and when the beans are roasted, most of these acids begin to break down. Some produce the brown-coloured compounds that give coffee its characteristic dark colour, while others produce the bitter-tasting chemicals responsible for its taste. Coffee also contains high quantities of caffeine, around 100 milligrams (0.0035 ounces) in every cup. It works on receptors in the heart and brain, blocking the action of a natural neurotransmitter and acting as a stimulant.

## Bacon

The distinctive smell of bacon is, as most of us have probably experienced, hard to resist. That fact is all down to the chemistry of cooking meat. As the bacon is heated, the amino acids that make up the muscle protein react with reducing sugars present in the bacon fat. This process, known as the Maillard reaction, occurs only at high temperatures and produces over 150 different volatile molecules, each able to interact with different smell receptors in the nose. Most of the delicious smell of bacon is attributed to a group of nitrogen-containing compounds known as pyridines and pyrazines.

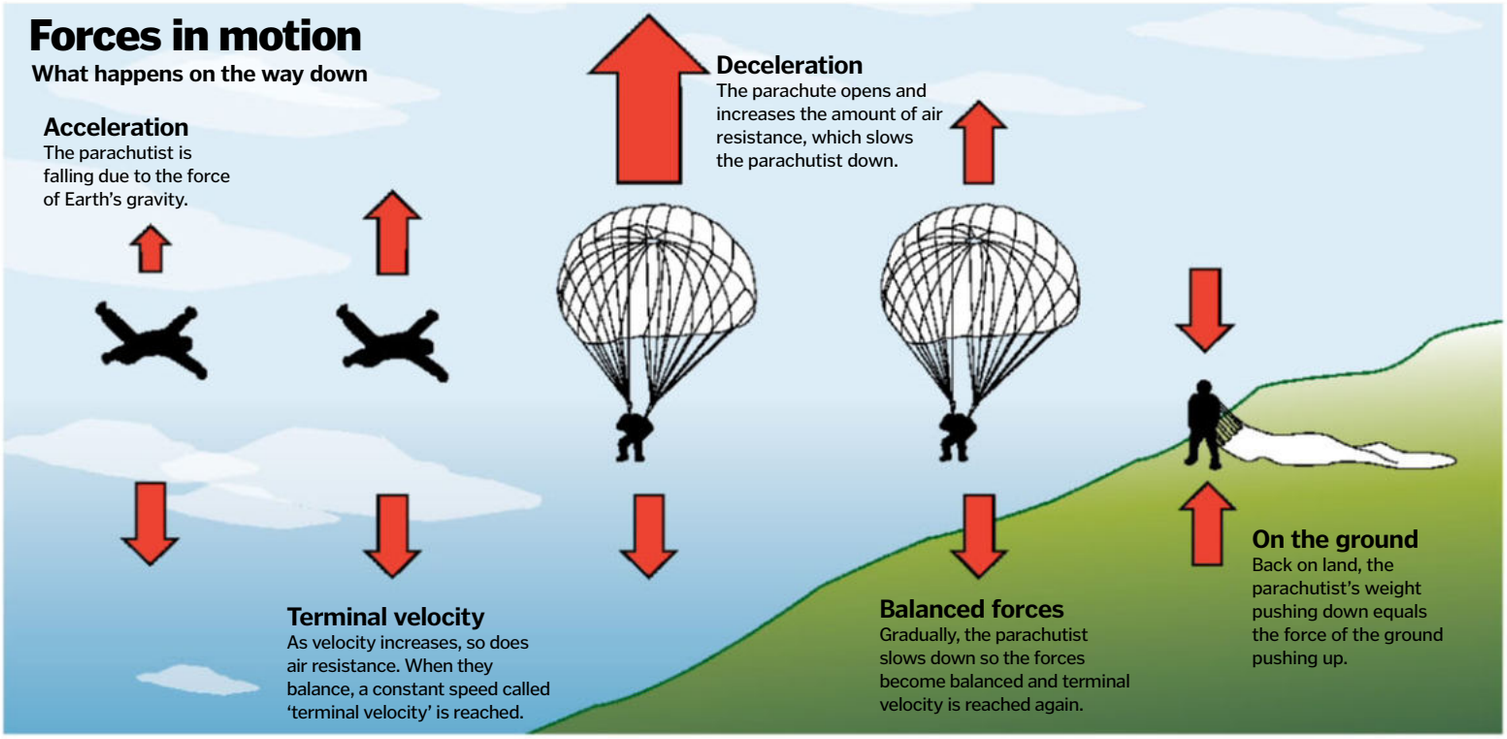
"Newer models of parachute are designed with flaps that make them act more like wings"

# How do parachutes slow you down?

## The physics that make skydiving safer

As an object falls from the sky, it's obeying the force of gravity. The counterbalance to gravity is air resistance, or drag, but this is not sufficient to stop an object falling to Earth. One way to increase drag is to use a parachute. This canopy fills with air, which slows the falling object as the uprush of air molecules have to push against the material.

Some newer models of parachute are designed with flaps that make them act more like wings, providing the user with upward thrust, slowing the descent even more. However, this does propel the user forward so more control is needed as landings now happen at a bit of a run.





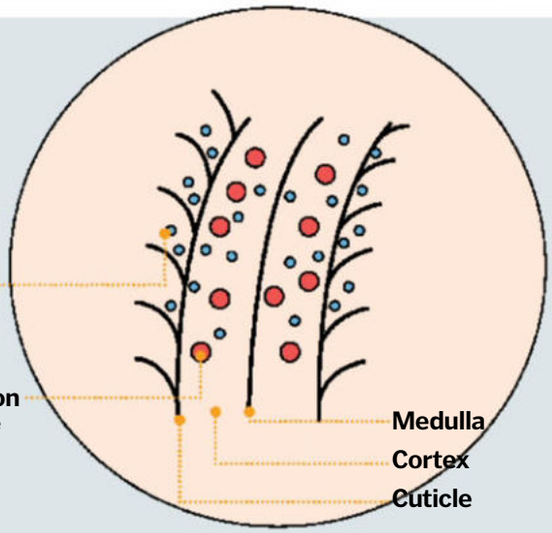

# Hair-colour chemistry

## How hair dye transforms your look

Dyeing hair goes all the way back to Ancient Egypt and has involved natural ingredients like ash, henna and turmeric through history. However, modern hair dyes are a cocktail of chemicals.

For the dye to penetrate the hair, it needs to get past the outer layer of the hair shaft, known as the cuticle. Ammonia is often used to do this as it is an alkali that raises the pH levels of the hair so the cuticle relaxes.

Then, peroxide is used to break the chemical bonds of your natural hair colour, which releases sulphur – the characteristic smell of hair dye. As the natural pigment is removed, the new permanent colour bonds to the hair cortex and conditioners seal the cuticle.



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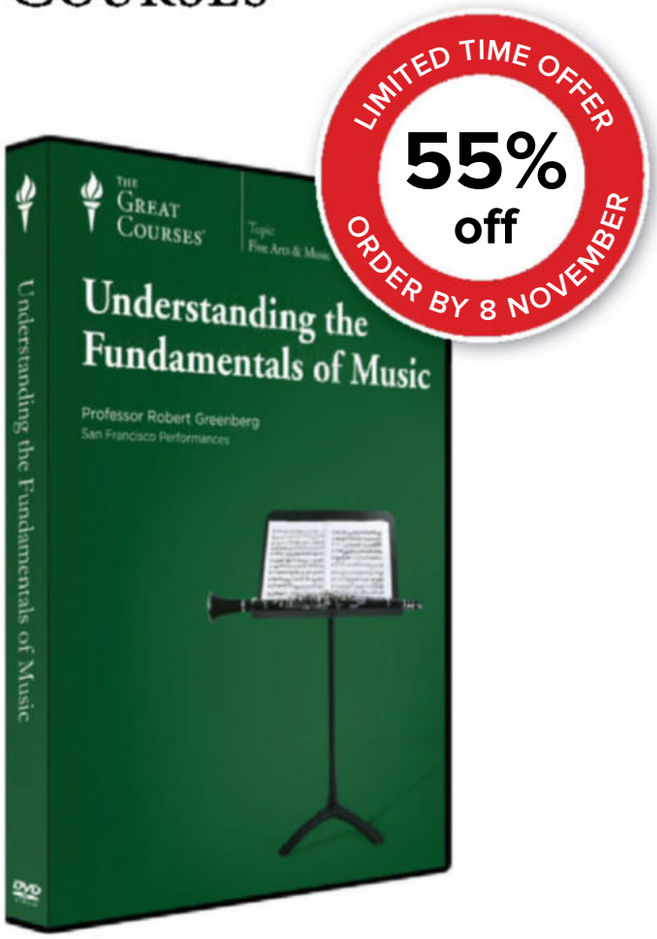


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"The dentist will first remove the problem tooth, aiming to leave as much of the jawbone intact as possible"

# Dental implants

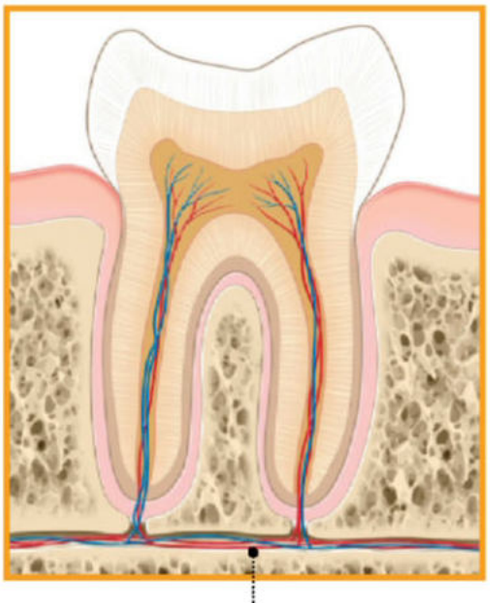
## Why people are ditching dentures for screw-in teeth

For thousands of years, broken or rotten teeth were replaced by uncomfortable false ones or dentures. Now, implants are among the latest tools in dentistry that are making tooth substitution effortless and painless.

The dentist will first remove the problem tooth, aiming to leave as much of the jawbone intact as possible. Next, they will insert a carefully measured tooth into the gap and secure it in place with a titanium screw that locks onto the jawbone, much like the root of a tooth would.

If there's not enough bone for the screw to lock into, the dentist may graft some bone into the gum so the screw can be secured.

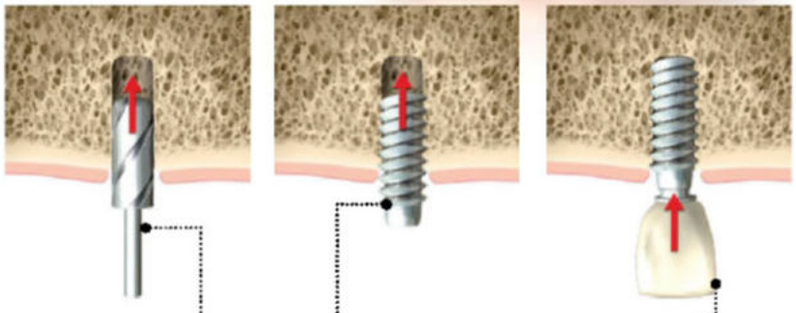
After a few months, the jawbone and screw should fuse together, creating a strong, stable tooth replacement with minimal pain.



### Extraction
The tooth is pulled out, trying to leave as much of the jawbone intact as possible.

## The process of dental implants

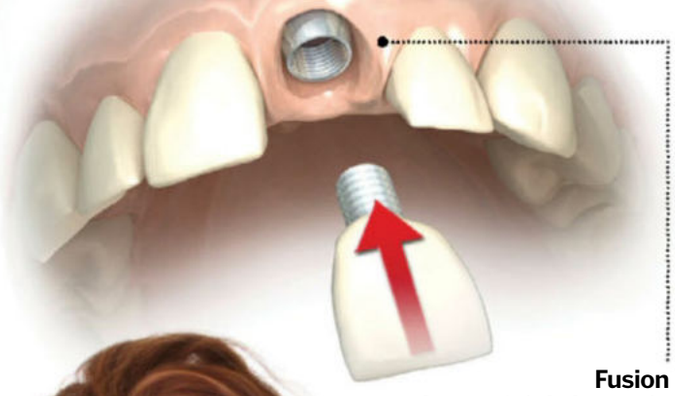
### What's the problem?
The problem tooth is identified and it is determined if extraction is needed.



### Making the hole
A hole is created in the gum for the new tooth to be put into.

### Screw in
The screw is inserted through the gum, into the jawbone to secure it.

### Tooth placement
The new tooth is put in position. It has to be very precisely placed and sized.



### Fusion
Over a period of a few months the jawbone and screw should fuse together so the tooth acts as a normal tooth.

# Why people faint

## Whether it's a swoon or shock, what causes that momentary collapse?

The brain functions because of oxygen carried to it in blood. Fainting can happen when the blood flow to the brain is reduced, usually because of a temporary malfunction in the nervous system. This can be caused by pain, stress or even standing up too quickly and people can feel dizzy and fall over. Lying down helps blood to continue flowing to the brain and the person will normally regain consciousness after a minute or two.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"The sunlight the plant gathers energises the electrons within the leaves"

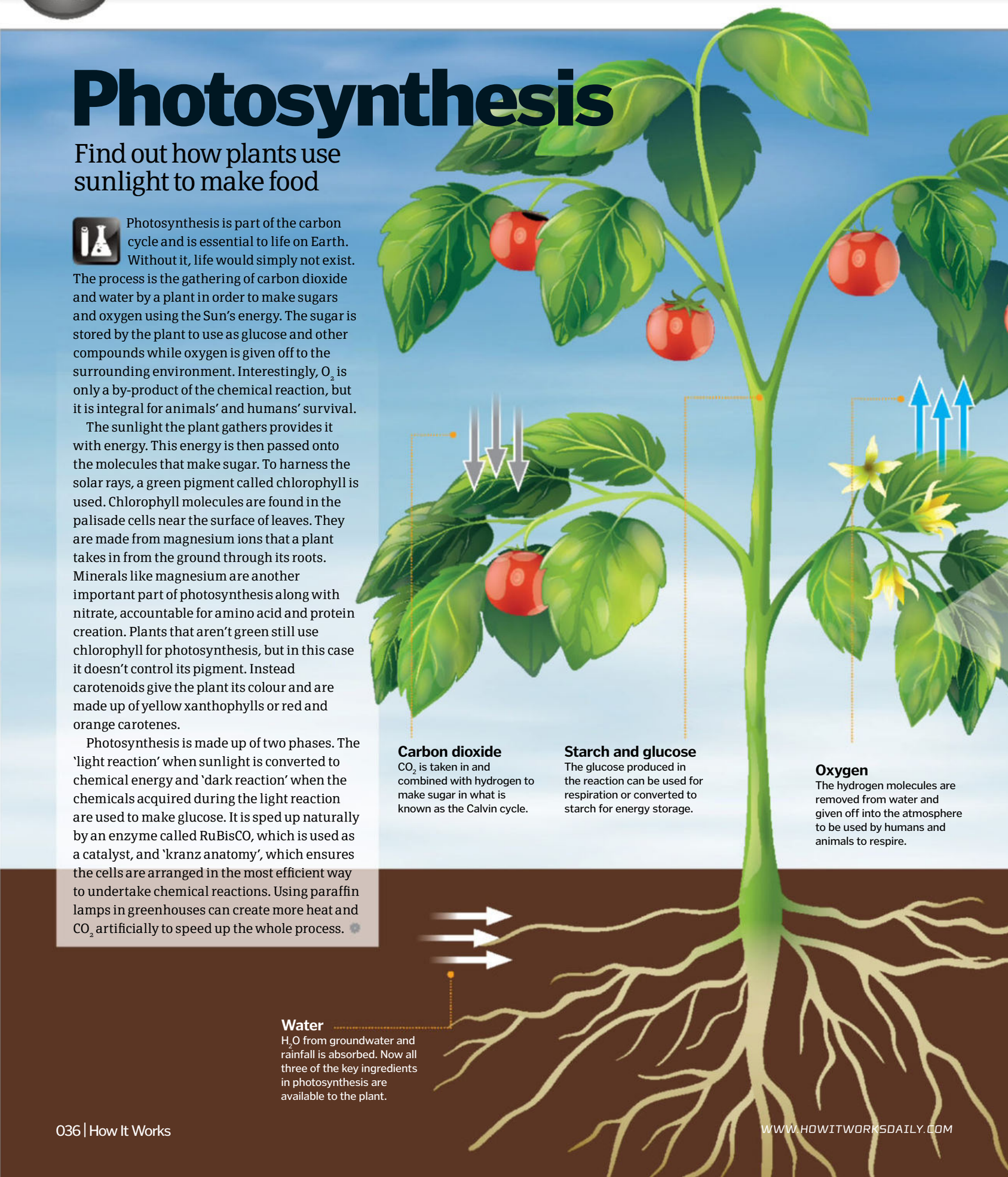
# Photosynthesis

## Find out how plants use sunlight to make food

Photosynthesis is part of the carbon cycle and is essential to life on Earth. Without it, life would simply not exist. The process is the gathering of carbon dioxide and water by a plant in order to make sugars and oxygen using the Sun's energy. The sugar is stored by the plant to use as glucose and other compounds while oxygen is given off to the surrounding environment. Interestingly, $O_2$ is only a by-product of the chemical reaction, but it is integral for animals' and humans' survival.

The sunlight the plant gathers provides it with energy. This energy is then passed onto the molecules that make sugar. To harness the solar rays, a green pigment called chlorophyll is used. Chlorophyll molecules are found in the palisade cells near the surface of leaves. They are made from magnesium ions that a plant takes in from the ground through its roots. Minerals like magnesium are another important part of photosynthesis along with nitrate, accountable for amino acid and protein creation. Plants that aren't green still use chlorophyll for photosynthesis, but in this case it doesn't control its pigment. Instead carotenoids give the plant its colour and are made up of yellow xanthophylls or red and orange carotenes.

Photosynthesis is made up of two phases. The 'light reaction' when sunlight is converted to chemical energy and 'dark reaction' when the chemicals acquired during the light reaction are used to make glucose. It is sped up naturally by an enzyme called RuBisCO, which is used as a catalyst, and 'kranz anatomy', which ensures the cells are arranged in the most efficient way to undertake chemical reactions. Using paraffin lamps in greenhouses can create more heat and $CO_2$ artificially to speed up the whole process.



**Carbon dioxide**
$CO_2$ is taken in and combined with hydrogen to make sugar in what is known as the Calvin cycle.

**Starch and glucose**
The glucose produced in the reaction can be used for respiration or converted to starch for energy storage.

**Oxygen**
The hydrogen molecules are removed from water and given off into the atmosphere to be used by humans and animals to respire.

**Water**
$H_2O$ from groundwater and rainfall is absorbed. Now all three of the key ingredients in photosynthesis are available to the plant.

# 5 TOP FACTS
## PHOTOSYNTHESIS IN ORGANISMS

**1 Algae**
A type of eukaryotic organism, algae convert light to chemical energy and account for 50 per cent of all photosynthesis undertaken on Earth.

**2 Sea slug**
A diet of algae means the ocean-dwelling sea slug can steal chloroplasts from seaweed and use it within their own cells.

**3 Oriental hornet**
These winged creepy crawlies have a yellow band across their abdomen that absorbs light and converts it to electricity – sort of like the solar panels of the animal kingdom!

**4 Pea aphid**
Rather than using chloroplasts and chlorophyll, aphids contain carotenoids, which give it photosynthetic abilities although more research is required to confirm this.

**5 Spotted salamander**
The first vertebrate that has been proven to photosynthesise, chlorophyll has been found in the amphibians' embryonic cells and being used in the same process as mitochondria.

**DID YOU KNOW?** *Photosynthesis isn't very efficient – over 60 per cent of the solar energy is not used by the plant*

**Sunlight**
The process begins as the plant takes in sunlight through the chloroplasts in its leaves.

**Cytoplasm**
The enzyme RuBisCO that is used in photosynthesis is created in this part of the leaf.

**Chloroplasts**
The light energy is trapped by chlorophyll and used to make glucose as a form of food for the plant.

**Cell wall and stomata**
The opening in the leaf epidermis and cuticle allows $CO_2$ to be released and oxygen to be taken in.

## The three types of photosynthesis

### 1 C3
The process a majority of plants on Earth use, C3 is so called because the carbon dioxide is turned into a three-carbon compound. Photosynthesis is carried out throughout the whole of the leaf and the process is the most efficient of the three types as it uses the fewest enzymes.

C3 photosynthesis is the most common of the three types and was the only type known until recent study

### 2 C4
Using a four-carbon compound, the photosynthesis only takes place in the inner cells of the plant. C4 is frequently used when the plant is under a high light intensity as it keeps oxygen levels low. This gives it a better water efficiency so it is a process that is used primarily in summer plants.

C4 is used in plants that receive large amounts of light and heat, such as corn

### 3 CAM
The $CO_2$ in this type of photosynthesis is originally stored as an acid and works during the night, not the day. The tiny openings in leaves (called stomata) only open in the dark as evaporation rate is lower at this time. It gives this type of process an advantage in dry conditions and is common in cacti.

Cacti use CAM, a process suited to plants that face tough, arid conditions

## The photosynthesis equation

$$6CO_2 + 6H_2O \xrightarrow{\text{LIGHT ENERGY}} C_6H_{12}O_6 + 6O_2$$

Carbon dioxide + water (+ light energy) → glucose + oxygen

# THE WORLD OF BIOMETRICS

## How fingerprint scans and other technologies can identify you

In today's connected world, the need to verify our identity comes up countless times each day. Right now, we tend to do that by one of two means: with a physical token like a passport or a door key, or with a piece of knowledge like a password or PIN. But physical ID can be lost or counterfeited, and passwords can be stolen, hacked or simply forgotten.

Enter biometrics. Instead of relying on tokens or knowledge, biometrics uses distinctive measurable characteristics about a person to identify them. Because these are unique to individuals, they make more reliable identifiers, are tough to copy and are impossible to forget. Biometric identifiers are grouped into physiological characteristics, like fingerprints, iris patterns and vein geometry; and behavioural traits, like the way a person types, talks or walks.

Biometric identifications all begin with some form of scan or data collection. This information is then encoded. In the past, this step would be done manually, for example noting the locations of distinctive features in fingerprints, but nowadays computers convert these into numerical code. Finally, these mathematical descriptions get compared to a database in search of a match.

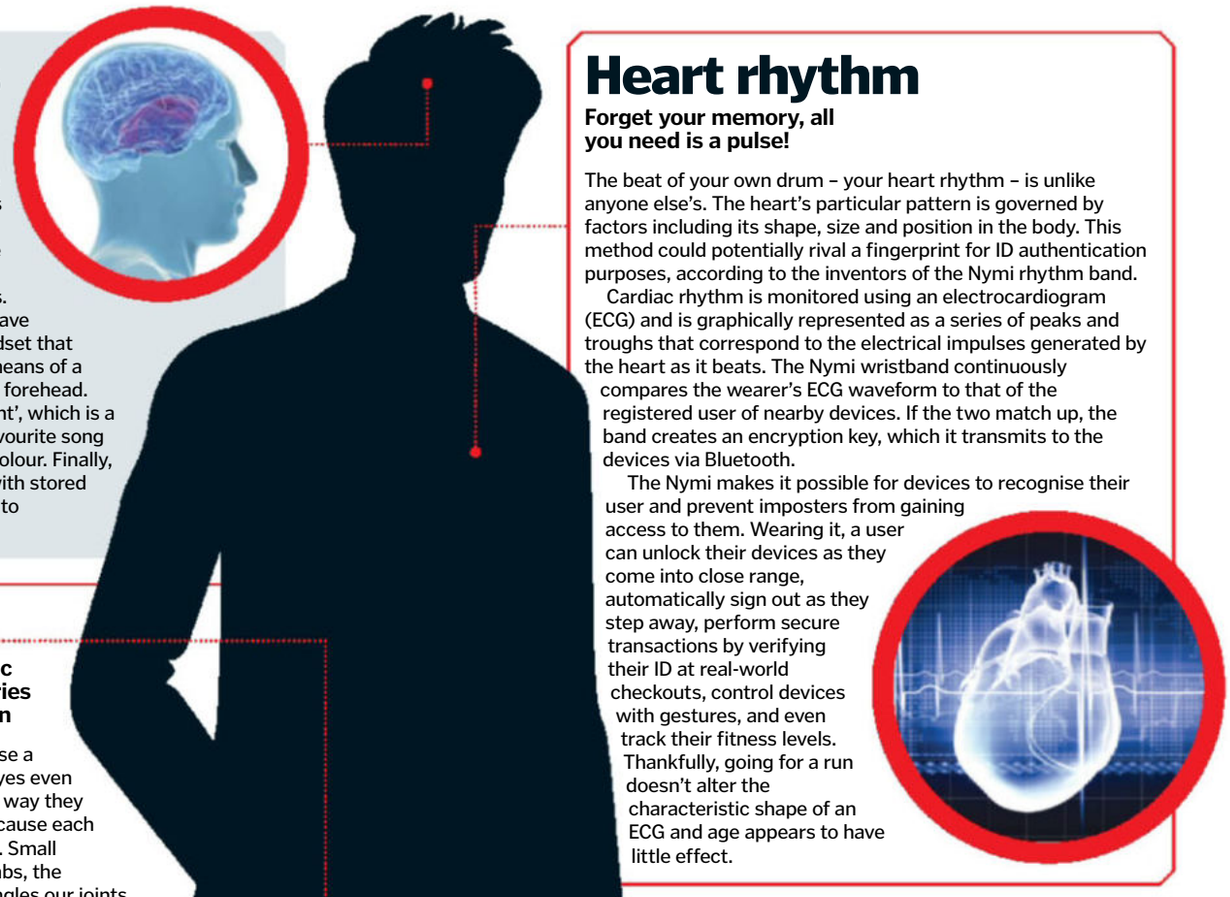
Biometrics can be used in a variety of settings; in national border control or high-security data, website and physical access. It can also monitor who is entering and leaving a workplace or to ensure hospital patients are correctly identified, as well as in law enforcement and security surveillance. Read on to learn about how your unique physical and behavioural characteristics can act as your new password for everything!

# 129 MILLION

## FINGERPRINT ID SPEED RECORD

The number of fingerprints searched in less than one second by the world's fastest automatic identification system – DERMALOG Next Generation AFIS. At ten prints per person, that's more than the entire population of Portugal.

**DID YOU KNOW?** *Four in ten UK secondary schools now use biometric technology as a means of identifying pupils*



## Brain waves

**Great minds think alike, but signal differently**

Even when two people think of the same thing, the electrical impulses in their brains differ slightly. Brain-wave biometrics exploits the fact that we all produce distinct patterns of alpha-beta brain waves.

To perform a biometric brain-wave authentication, a user dons a headset that measures their brain activity by means of a single dry-contact sensor on their forehead. Next, they think their 'pass-thought', which is a mental task such as recalling a favourite song or counting objects of a specific colour. Finally, their brain waves are compared with stored recordings of their pass-thoughts to authenticate their identity.

## Heart rhythm

**Forget your memory, all you need is a pulse!**

The beat of your own drum – your heart rhythm – is unlike anyone else's. The heart's particular pattern is governed by factors including its shape, size and position in the body. This method could potentially rival a fingerprint for ID authentication purposes, according to the inventors of the Nymi rhythm band.

Cardiac rhythm is monitored using an electrocardiogram (ECG) and is graphically represented as a series of peaks and troughs that correspond to the electrical impulses generated by the heart as it beats. The Nymi wristband continuously compares the wearer's ECG waveform to that of the registered user of nearby devices. If the two match up, the band creates an encryption key, which it transmits to the devices via Bluetooth.

The Nymi makes it possible for devices to recognise their user and prevent imposters from gaining access to them. Wearing it, a user can unlock their devices as they come into close range, automatically sign out as they step away, perform secure transactions by verifying their ID at real-world checkouts, control devices with gestures, and even track their fitness levels. Thankfully, going for a run doesn't alter the characteristic shape of an ECG and age appears to have little effect.



## Gait

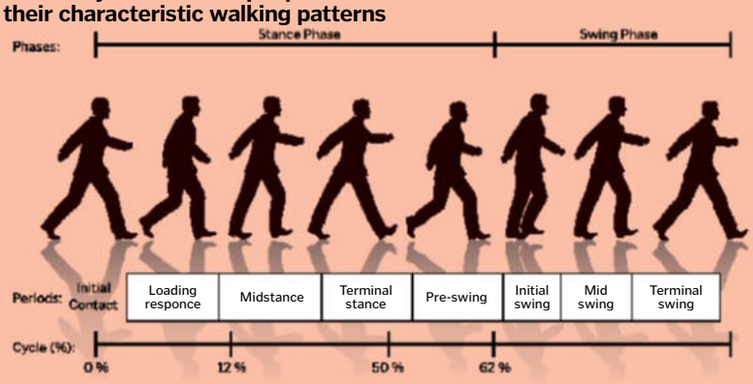
**Although humans share basic movement patterns, gait varies widely from person to person**

Ever noticed how you can recognise a friend approaching, before your eyes even focus on the details, just from the way they cut through the crowd? That's because each person's walk – or gait – is unique. Small variations in the lengths of our limbs, the dimensions of our muscles, the angles our joints make, and the complex way our muscles fire in sequence to propel us forward means that each and every one of us has a characteristic lope.

A gait analysis studies a multitude of movement parameters from video footage or sensor information – including a person's walking speed, stride length, step width, the angles of their joints in motion, and how their joints rotate and respond to the varying kinetic forces throughout their stride – and converts this into a mathematical description of a person's walk. Gait analysis is unobtrusive; it requires no physical contact with the subject and can even be done in secret to identify criminals.

## Walk this way

**Gait analysis identifies people based on their characteristic walking patterns**




The stance and swing phases are when the lead foot is and isn't in contact with the ground, respectively. The timings of each phase are unique due to your musculoskeletal make-up.

## Vein matching

**No two people have identical veins – not even identical twins!**

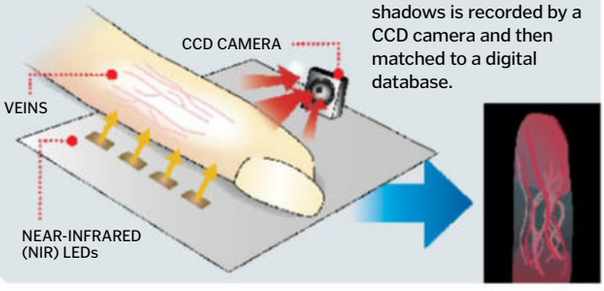
Just like fingerprints, everybody's vein geometry is completely unique and remains the same throughout their lives. Unlike fingerprints, however, vascular patterns are almost impossible to counterfeit because of the vessels' location beneath the skin's surface.

To map a person's veins, their hand or finger is placed into a scanner and illuminated with near-infrared light. A CCD digital camera takes a picture and, because haemoglobin in the blood absorbs the light but the surrounding tissues do not, the veins show up in the picture as black lines. Geometric details such as vein thickness, branching points and branching angles are extracted and mapped for comparison.

## In a similar vein

**Vein matching identifies a person by their unique vascular geometry**

The light from a near-infrared light source penetrates the skin and is absorbed by veins but transmitted by other tissues. The pattern of shadows is recorded by a CCD camera and then matched to a digital database.



"Automatic facial recognition systems analyse the contours of faces to identify individuals"

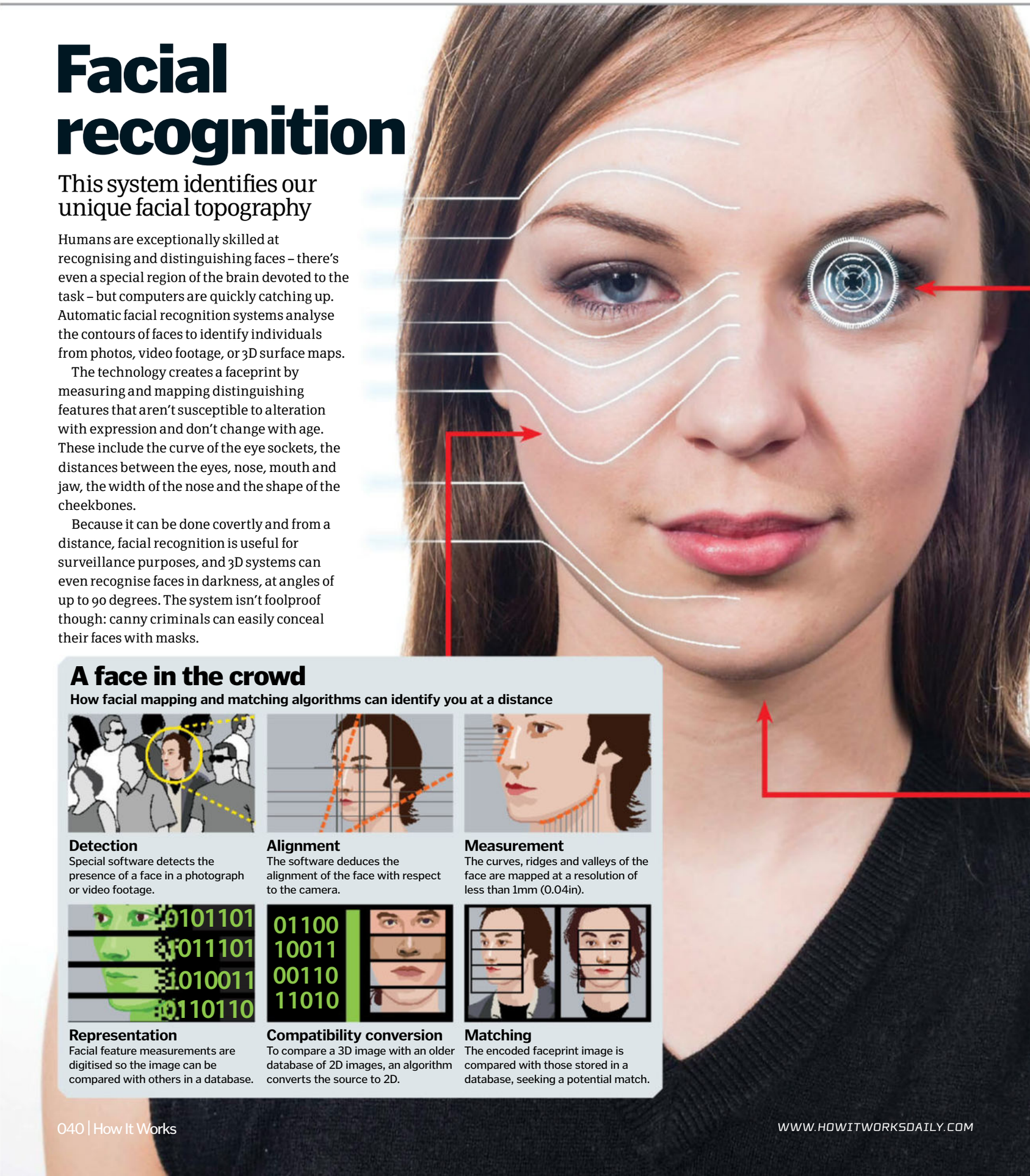
# Facial recognition

## This system identifies our unique facial topography

Humans are exceptionally skilled at recognising and distinguishing faces – there's even a special region of the brain devoted to the task – but computers are quickly catching up. Automatic facial recognition systems analyse the contours of faces to identify individuals from photos, video footage, or 3D surface maps.

The technology creates a faceprint by measuring and mapping distinguishing features that aren't susceptible to alteration with expression and don't change with age. These include the curve of the eye sockets, the distances between the eyes, nose, mouth and jaw, the width of the nose and the shape of the cheekbones.

Because it can be done covertly and from a distance, facial recognition is useful for surveillance purposes, and 3D systems can even recognise faces in darkness, at angles of up to 90 degrees. The system isn't foolproof though: canny criminals can easily conceal their faces with masks.



## A face in the crowd

**How facial mapping and matching algorithms can identify you at a distance**



**Detection**
Special software detects the presence of a face in a photograph or video footage.



**Alignment**
The software deduces the alignment of the face with respect to the camera.



**Measurement**
The curves, ridges and valleys of the face are mapped at a resolution of less than 1mm (0.04in).




**Representation**
Facial feature measurements are digitised so the image can be compared with others in a database.




**Compatibility conversion**
To compare a 3D image with an older database of 2D images, an algorithm converts the source to 2D.



**Matching**
The encoded faceprint image is compared with those stored in a database, seeking a potential match.

## KEY DATES
### BIOMETRIC IDENTIFICATION

**2000 BCE**
Evidence suggests fingerprints were used on clay tablets in transactions in Ancient Babylon.

**1870s**
Alphonse Bertillon's anthropometrics catalogue and identify serial criminals by their body measurements.

**1892**
Sir Francis Galton develops a fingerprint classification system using prints from all ten fingers.

**1994**
The world's first successful iris-recognition algorithm is patented by Dr John Daugman.

**2013**
India's Aadhaar project finishes capturing biometric data of over half a billion residents, making it the world's largest biometric database.

**DID YOU KNOW?** *The Canadian Kennel Club has been accepting dog-nose prints as proof of identity since 1938*

# Iris scanning

**This tech has gone from science fiction to science fact**

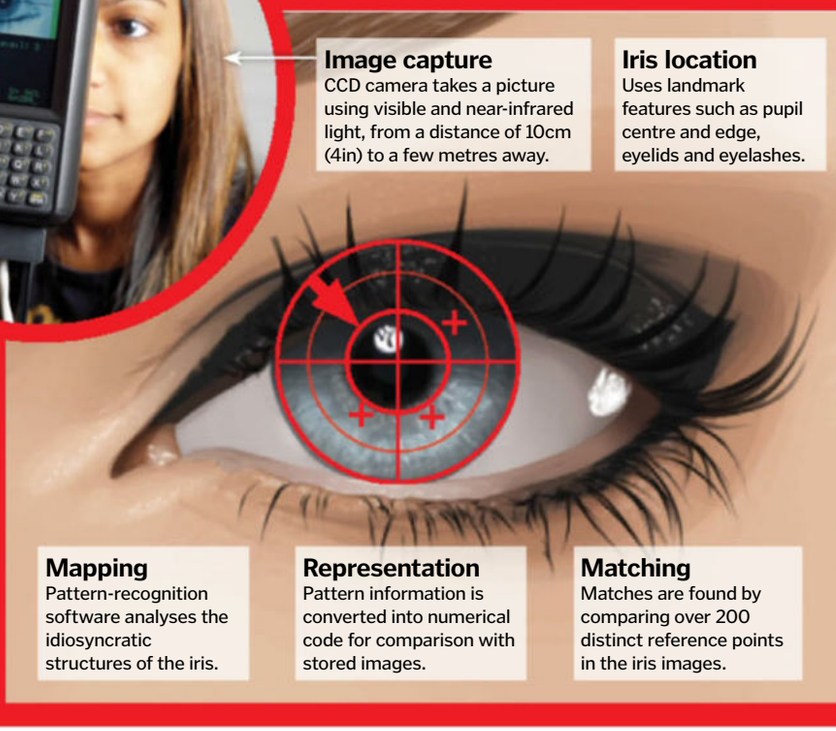
Iris scanning is underpinned by the fact that no two irises – the textured coloured muscle that regulates the size of your pupil – are identical. They develop randomly in the womb, form fully by eight months of age, and remain stable throughout the rest of a person's life.

During an iris scan, a CCD digital camera takes a high-contrast picture of your eye using both visible and near-infrared light. The iris is located in the image via landmarks including the pupil edge and eyelids, and pattern-recognition software maps the iris's distinct structure of furrows, speckles and ridges.

Iris-recognition systems are among the most accurate of all biometric technologies, and offer more than 200 reference points for comparison (compared to 60 to 70 points in fingerprints). Iris scanning should not be confused with retinal scanning, which compares the patterns of blood vessels on the back of the eye.

**Image capture**
CCD camera takes a picture using visible and near-infrared light, from a distance of 10cm (4in) to a few metres away.

**Iris location**
Uses landmark features such as pupil centre and edge, eyelids and eyelashes.



**Mapping**
Pattern-recognition software analyses the idiosyncratic structures of the iris.

**Representation**
Pattern information is converted into numerical code for comparison with stored images.

**Matching**
Matches are found by comparing over 200 distinct reference points in the iris images.


# Voice recognition

**You – and your dulcet tones – are a truly singular voice**

The sound of your voice is governed by physiological factors – the shape of your vocal tract, airways and surrounding soft-tissue cavities – as well as behavioural factors, linked to personality and peer influence, which affect the motion of your mouth as you speak. Together, these mean that everyone's voice is distinct.

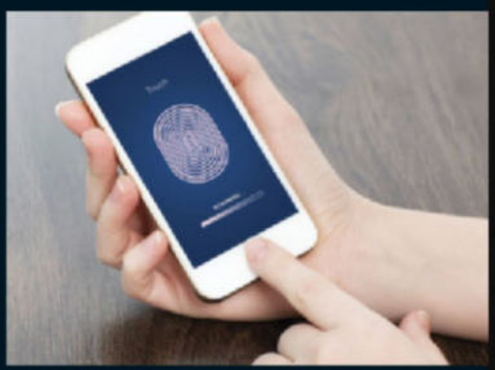
Voice-recognition systems record a spectrogram of how sound frequency varies with time. Qualities like the acoustic characteristics and intensity dynamics of the speaker's voice are extracted and used to identify them.

Simple voice-authentication systems require a person to speak a previously recorded password, but these can be vulnerable if a hacker has a recording of a person saying their password. More advanced systems prompt a user to say a random word and authenticate this against a complete profile of the person's voice.

"Our fingerprints form randomly in the womb and remain unchanged throughout our lives"

# Fingerprinting

## How smartphone and airport fingerprint scanners work



Fingerprint identification is the oldest and most widely used biometric method. Our fingerprints – the pattern of loops, whorls and arches – form randomly in the womb and remain unchanged throughout our lives. Like snowflakes, there are infinite pattern possibilities and scientists believe no two fingerprints are ever formed the same way.

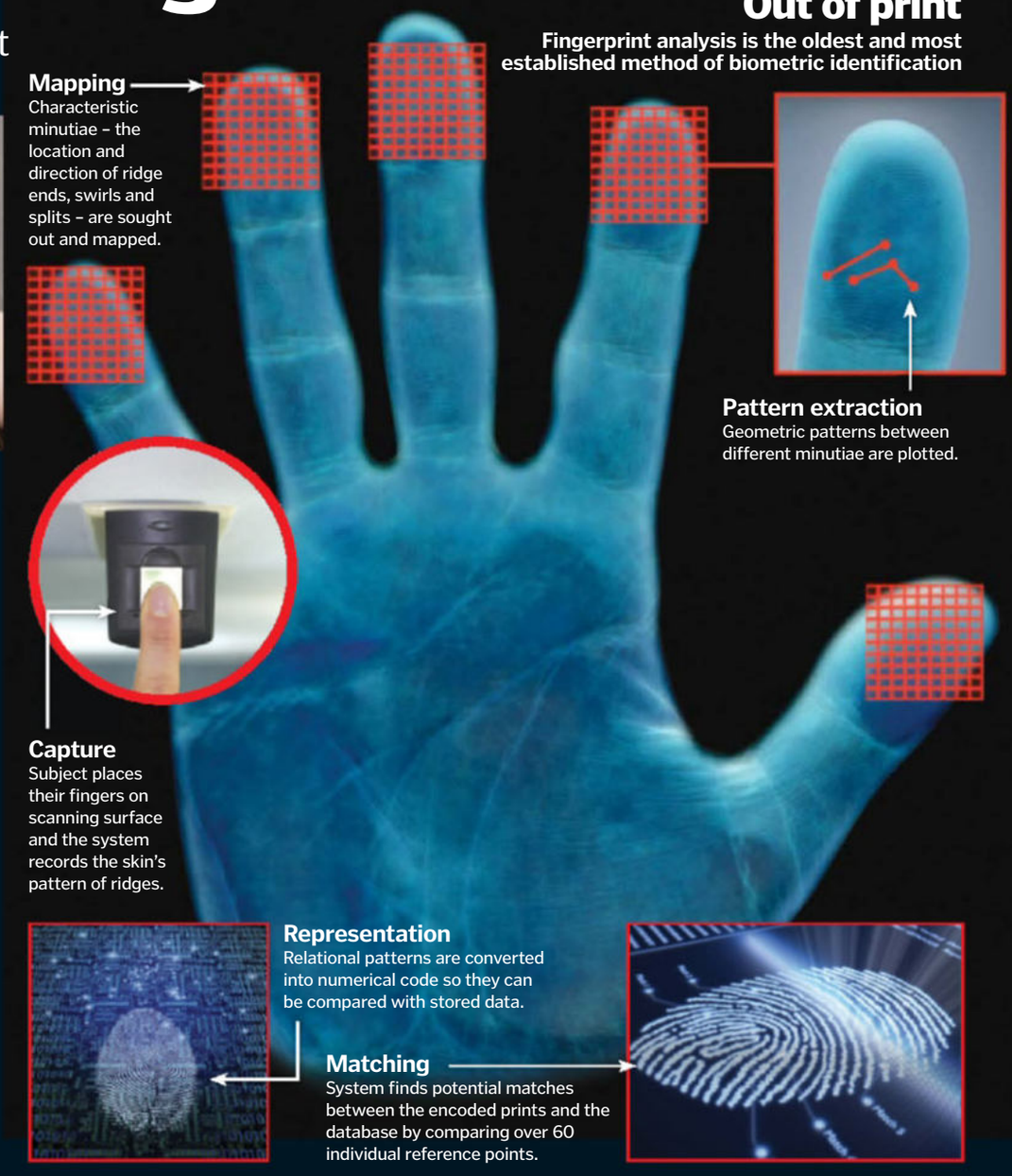
Although there is evidence that fingerprints were used as a person's mark or signature in Ancient Babylon, they have been systematically used to identify people since 1892, when Sir Francis Galton developed a way to classify ten-finger print sets. Galton identified common local features in fingerprints – like where the ridges start, end and split along their paths – which became known as 'Galton Points.'

Galton's legacy lives on in today's fingerprint matching, which uses the location and orientation of a subset of his points, called minutiae. With the advent of computing technology in the 1960s, fingerprint matching became automated. Today, the FBI's IAFIS (Integrated Automated Fingerprint Identification System) – holds over 100 million individuals' prints and performs over 60 million searches on the database per year.

Prints are collected by a variety of means. They can be lifted from a crime scene using fine powder or reactive chemicals, or they can be taken from a person by inking their fingers and stamping them on paper. More recently, they can be captured digitally with a variety of sensors, including optical, thermal and capacitance sensors. Sophisticated computer algorithms analyse the minutiae patterns in the prints and look for matches in a database.

## Out of print

**Fingerprint analysis is the oldest and most established method of biometric identification**



**Mapping**
Characteristic minutiae – the location and direction of ridge ends, swirls and splits – are sought out and mapped.

**Pattern extraction**
Geometric patterns between different minutiae are plotted.

**Capture**
Subject places their fingers on scanning surface and the system records the skin's pattern of ridges.

**Representation**
Relational patterns are converted into numerical code so they can be compared with stored data.

**Matching**
System finds potential matches between the encoded prints and the database by comparing over 60 individual reference points.

## Are fingerprints really unique?

Fingerprint evidence has been a staple of forensic investigations for over a century and is considered to be conclusive proof of a suspect having been at a crime scene. But some experts contend the underlying principle that no two fingerprints are alike. The predominant patterns in your prints – whorls, loops or arches – run strongly in families and, while evidence suggests it is improbable, proving that no two people have identical prints is practically impossible.

Even if they truly are unique, the collection and identification process can be prone to human error. Crime scene fingerprints can be partial, smudged or degraded, and the exact print left by an individual finger can vary slightly from one impression to the next. Also, humans aren't alone in having fingerprints. Chimps, orangutans and koalas all share the trait and their prints could easily be mistaken for human ones at an interspecies crime scene.

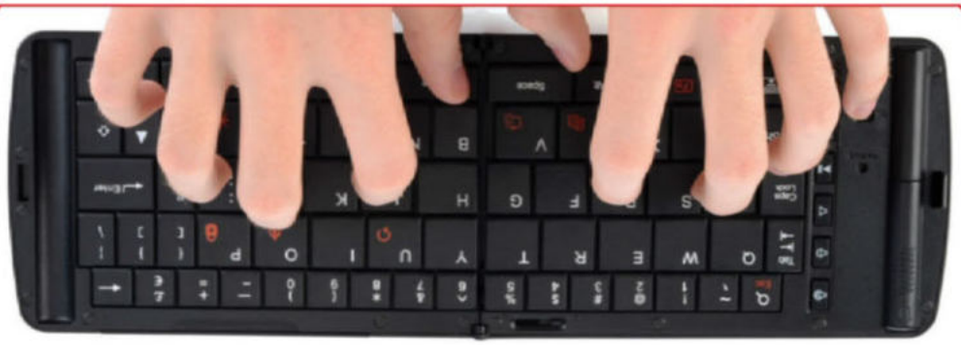
Studies show that even experts are prone to mistakes, coming to different conclusions than their peers and even identifying the same set of prints differently on second glance. This, at least, is one weakness that automated fingerprint identification by computers can banish, reducing the risk of false convictions and unjust punishment.

**AMAZING VIDEO!** SCAN THE QR CODE FOR A QUICK LINK

**See how facial recognition could impact our lives**

www.howitworksdaily.com

**DID YOU KNOW?** *The word biometrics derives from the Greek for 'life' and 'measure' and was first used in 1902*



# Keystroke recognition

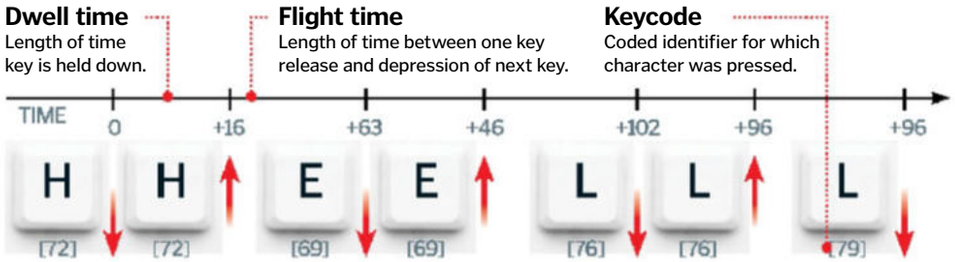
**Your typing rhythm is as distinctive as your handwriting or signature**

Typing rhythms are idiosyncratic because each of us has particular characters that always seem to evade us and certain common letter combinations that fly from our fingers faster than the rest. Keystroke recognition analyses the rhythm and features of a person's typing style by logging nuances like how long they take to reach and depress a key (flight time) and how long they hold keys down (dwell time).

Keystroke-timing data can be collected from any keyboard and compared with stored pattern data to confirm the user is who they claim to be. But the technique is limited by the fact that, even though an individual's typing rhythm is independent of how fast or slow they type, other factors such as how tired they are or whether they have consumed alcohol can interfere with it.

## A certain type

**Keystroke recognition uses your typing rhythms to authenticate your identity**




Biometric typing sample format

0d72 | 16u72 | 63d69 | 46u69 | 102d76 | 96u79 ...

Relative time to last event — Down event — Up event — Keycode

# Biometric passports

**Biometric documents make identity fraud near impossible**

A passport is the ultimate proof of identity. Aside from your birth certificate, it is pretty much the last document you would ever want to be stolen or forged; a thief could wreak all sorts of havoc while assuming your identity, leaving you to deal with the consequences. National border-security agencies need to monitor exactly who enters and leaves their country, a need that, in these times of mass global travel and international terror threats, has become ever-more pressing.

A biometric passport, or e-passport, combines the paper passport of old with a tiny chip and an antenna that allows it to be read electronically. The chip is embedded into a page of the passport in such a way that it can't be tampered with. The chip contains the same basic data as the standard passport information page, plus encrypted digital images of one or more of the holder's biometrics.

When the holder steps up to the immigration window, the relevant biometrics are captured and then compared to those in the passport. All passports now issued in the UK are biometric, and contain information about the holder's face, such as the distances between the eyes, ears, nose and mouth.

# Biometric revolution

**Dr Arun Ross, associate professor of Computer Science and Engineering at Michigan State University, answers our questions on the burgeoning field of biometrics**

**What major advances have been made in biometrics in the last decade?**
**Arun Ross:** First, the matching accuracy of biometric systems has substantially improved. Second, it's now possible to search through large databases of identities very quickly, due to improvements in computational power and development of efficient indexing models. Third, a number of new sensors have been designed. For example, it's now possible to perform iris recognition at a distance.

**What kind of matching accuracies are we talking about?**
**Ross:** That depends on the kind of data you're working on. If you work with mugshots or high-quality fingerprint images, recognition rates can exceed 99 per cent. But if you're dealing with low-quality data from surveillance video, or degraded fingerprints that are lifted from a crime scene, the performance can drop to the 60s.

**Where are biometric identification techniques having the most impact?**
**Ross:** Early systems were mostly used by law enforcement for criminal investigations, but now we're seeing biometrics being incorporated into border security systems and national ID card programs. We're also seeing biometrics enter the consumer electronics market, including smartphones. This is likely to become commonplace as we conduct more and more sensitive transactions online, so the need to verify our identities becomes especially important.

**What are some of the ethical or security concerns surrounding biometric data collection and storage?**
**Ross:** One concern is whether data will be used for purposes outside those expressed at the time of collection – a phenomenon we refer to as function creep. There are also concerns over data theft and misuse. For example, can someone steal my fingerprint as it is being transmitted through cyberspace and play it back for another transaction, or create a fake fingerprint using the stolen data? Legal scholars and biometric researchers are working to see how these security and privacy concerns can be mitigated.

**What developments on the horizon strike you as most exciting?**
**Ross:** Many of us store, access and transmit extremely sensitive information – both personal and professional – using our smartphones, so incorporating biometric solutions into our phones will become important for applications such as online banking. In several countries in Africa, smartphone use is rapidly increasing as access to the internet becomes ubiquitous. Biometrics could be used to great effect there to, for example, verify identities remotely when people use their smartphones to access resources like microloans.

"Wi-Fi and Bluetooth connectivity is very useful for checking your social networks"

# Google Glass

## Merging the real and virtual worlds together

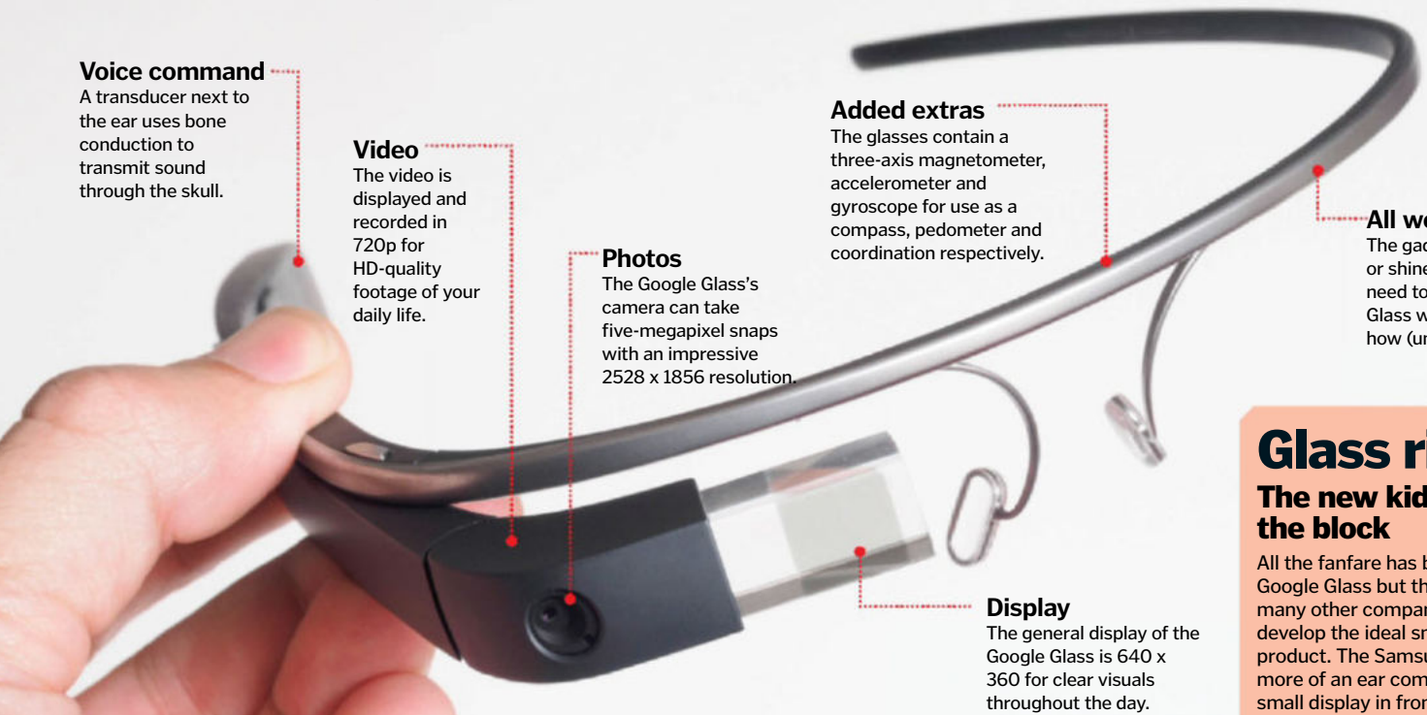
Computing giant Google has announced that its innovative Google Glass system is now available worldwide. But apart from looking seriously cool, what does it actually do? In short, Google Glass is a new type of smart eyewear or OHMD (optical head-mounted display) that can perform several different tasks, from seeing what you've got left on your shopping list to mapping out the golf course you're currently on.

The spectacle-like device can do all the basic things you'd expect from a modern smart gadget, such as playing music, acting as a compass and measuring the steps on your weekly jog but it also has more advanced features. The party trick of the device could well be its Bone Conduction Transducer, which rests just behind the ear. This transmits sound from the device through the bone of your skull to your inner ear.

Some of the features of Google Glass may be more of a novelty than others, such as recording videos by winking, for instance, but Wi-Fi and Bluetooth connectivity is very useful for checking your social networks or finding out how your favourite football team is getting on during a live match. Google Glass is expected to market at approximately £1,000 ($1,600) on its commercial launch and will originally be available to over-18s only. Despite this, some sources are predicting sales of 21 million units by 2018 so expect to see them almost everywhere in the very near future.

## Dissecting Glass

**What are these futuristic specs made up of?**



**Voice command**
A transducer next to the ear uses bone conduction to transmit sound through the skull.

**Video**
The video is displayed and recorded in 720p for HD-quality footage of your daily life.

**Photos**
The Google Glass's camera can take five-megapixel snaps with an impressive 2528 x 1856 resolution.

**Added extras**
The glasses contain a three-axis magnetometer, accelerometer and gyroscope for use as a compass, pedometer and coordination respectively.

**All weather**
The gadget can work rain or shine so you'll never need to buy tiny Google Glass wipers no matter how (un)cool it'll look.

**Display**
The general display of the Google Glass is 640 x 360 for clear visuals throughout the day.

"The spectacle-like device can do all the basic things you'd expect from a modern smart gadget [...] but it also has more advanced features"

The Google Glass video can record footage that will look exactly how you saw it first time round

## Glass rivals

### The new kids on the block

All the fanfare has been about the Google Glass but there are actually many other companies aiming to develop the ideal smart eyewear product. The Samsung Gear Blink is more of an ear computer with a small display in front of one eye, which will include a virtual reality keyboard. Also on the radar is the Sony Smart EyeGlass that will link up to Android phones in a very similar way to Google's device. Away from the major players, some smaller firms are also making inroads into the emerging market. The ChipSiP promises a HD resolution display while the Baidu Eye from China has no screen so will be a long-lasting and simpler alternative to the other products.


## The new M30 from Blue Aura

Delivers real Hi-Fi Sound, Easy to Use "Pair & Play" Bluetooth audio streaming
Connects to mobiles, laptops, TV's, tablets, internet radio.....
Styled, faux leather finish available in three colours
Wall mount, desk and speaker stand options
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**Watch the laser keyboard in action!**

www.howitworksdaily.com

**DID YOU KNOW?** *The laser keyboard is also available in a German QWERTZ format. Wunderbar!*

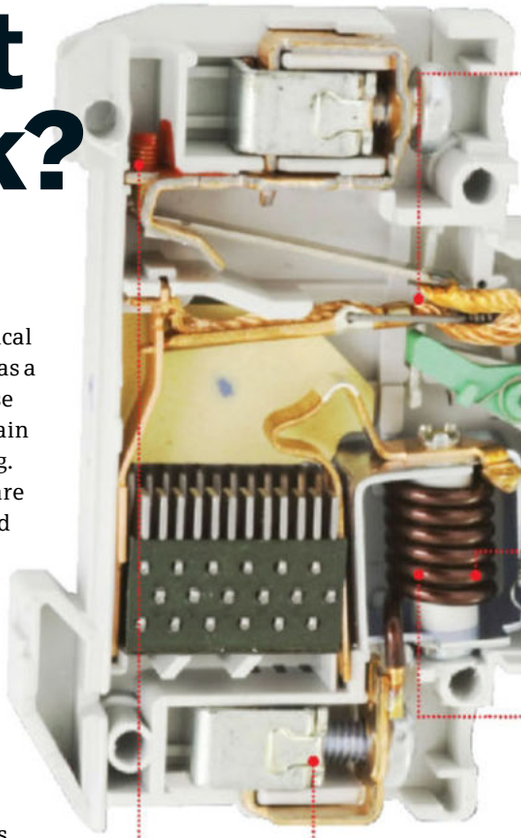
# How do circuit breakers work?

## Dissecting one of the most important household safety devices

Even at low voltages, electricity can be extremely dangerous. A circuit breaker is a safety mechanism that will cut the power when electrical wiring has too much current flowing through it. This prevents electric shocks, potential fires and the various other problems that could arise from an overload of electricity.

The mechanism's switch can be in either a closed or open position. It is held in the closed position by a spring-loaded bolt, which is controlled by an electromagnet. If the current reaches a set level, the electromagnet attracts the switch and the circuit is automatically broken, which halts the electrical charge. Each household also has a central circuit breaker (or a fuse box), which contains all the main circuit breakers in the building. High-voltage circuit breakers are also used in power stations and large electricity grids for the same purpose.

The circuit breaker does the same job as the fuse, but operates differently. A fuse contains a piece of wire that melts when the current is too great, breaking the circuit. Therefore, fuses have to be replaced while circuit breakers can be reset after a short circuit or power overload.



**Contacts**
This part of the circuit breaker allows the current to pass when the contacts touch and halt it when separated.

**Lever**
The handle can be raised or lowered by hand to join or break the circuit. This is also where it can be reset.

**Current**
As the current increases, the magnetism of the electromagnet also increases.

**Electromagnet**
The solenoid coil is an electromagnet that can break the current when the charge is too high.

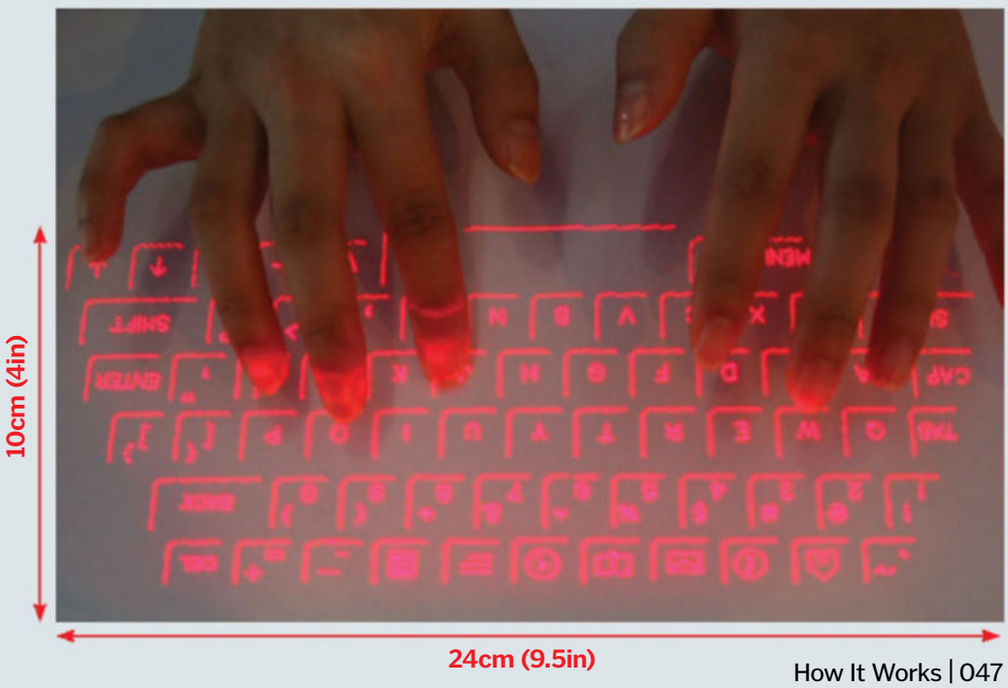
**Screw**
The current required to trip the system can be adjusted by an electrician.

**Terminals**
The electrical appliance is connected to the circuit breaker at this point.

# Laser keyboard

## Have a portable office in your pocket with weightless typing on the go

A newly developed laser keyboard could be ideal for quick word processing or emailing when commuting, as it contains no wires. Rather than a lumbering piece of plastic, this keyboard is simply a fixed laser pattern projection, which can turn any flat, opaque surface into a workstation. The only physical item is the pocket-sized projector module which beams the infrared light that creates the keyboard. Using Bluetooth and electronic perception technology, a virtual interface-processing core analyses the impact of your fingers on each key. The result is a full QWERTY keyboard that can be connected to Windows and Mac computers as well as iOS and Android systems. Boasting a 120-minute battery life from its lithium-ion polymer battery, the laser keyboard may seem like a gimmick to some, but it could be incredibly useful on a long journey.



"An initial opening is made first, which is held up by rock bolts and a shotcrete lining"

# How tunnels are made

## Discover the technology that blazes trails through solid rock

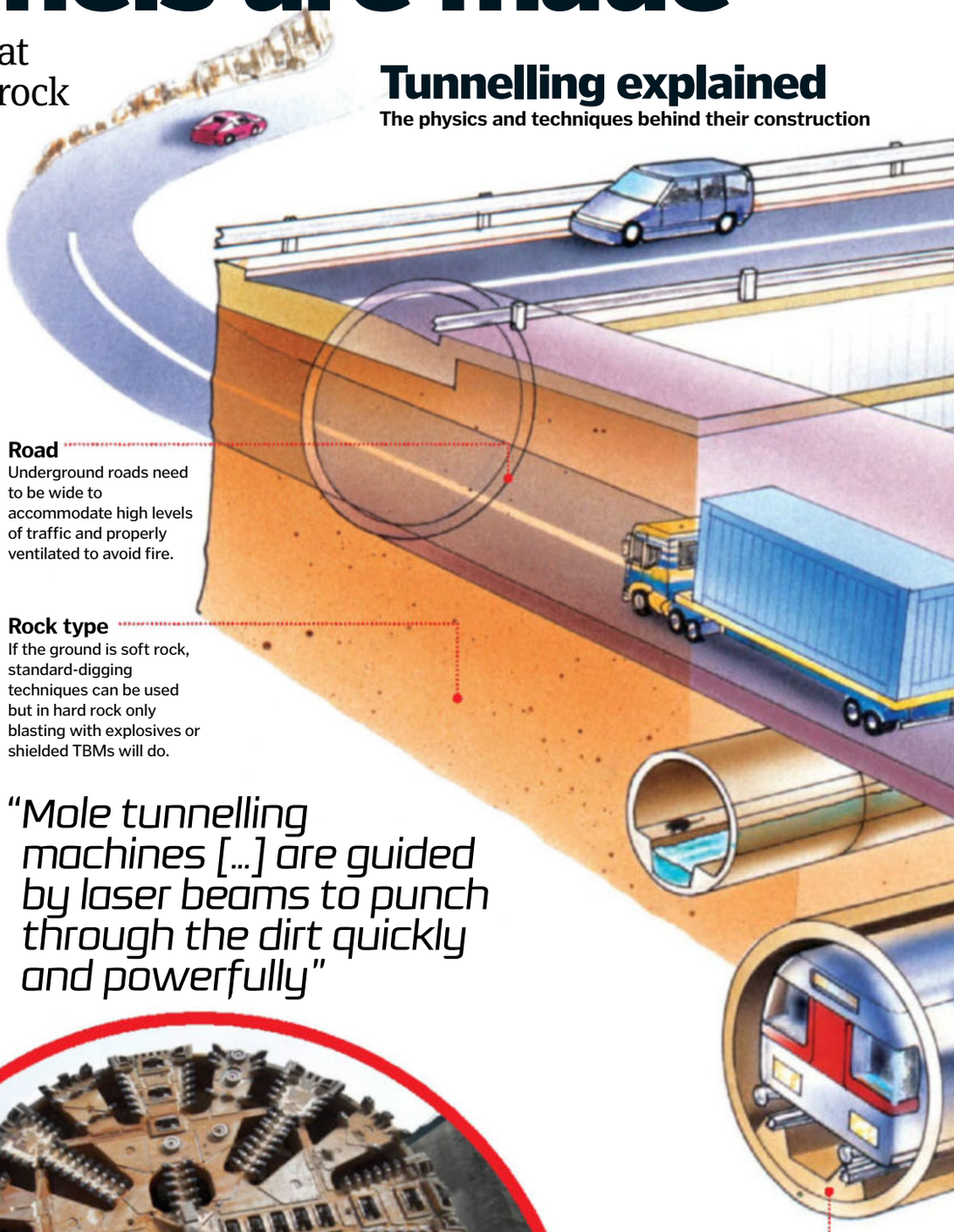
From mining to transport infrastructure and sewage control, tunnels are essential for an array of purposes. The longest in the world is the Delaware Aqueduct in the United States at an astonishing 137 kilometres (85.1 miles) long. The Seikan Tunnel, linking the Japanese islands of Honshu and Hokkaido, is the longest rail tunnel and spans a mighty 54 kilometres (33.4 miles). However, by 2016 it will be trumped by the Gotthard Base Tunnel (GBT) in Switzerland, which will be three kilometres (1.9 miles) longer.

To start a tunnelling project, you must first plan a geologic analysis of the area. By making a judgement on the rock and soil type, a construction's properties and dimensions can be adjusted accordingly. For example, you would use lighter materials and equipment on softer rock. An initial opening is made first, which is held up by rock bolts and a shotcrete lining to stop the structure from collapsing during construction. There must also be plenty of ventilation shafts to avoid any chance of suffocation, poisoning or heat exhaustion. Only then can the construction of a tunnel get under way in earnest.

Since 1954, large projects have used 'mole' tunnel boring machines that are guided by laser beams to punch through the dirt quickly and powerfully. A technique known as the immersed-tube method works by inserting prefabricated tunnels into a previously dug trench. This procedure has been found to be extremely effective, especially in underwater developments. In smaller constructions, hand tunnelling is still frequently used as it is much more cost effective than using a giant machine to carve pathways through rock.

## Tunnelling explained

**The physics and techniques behind their construction**

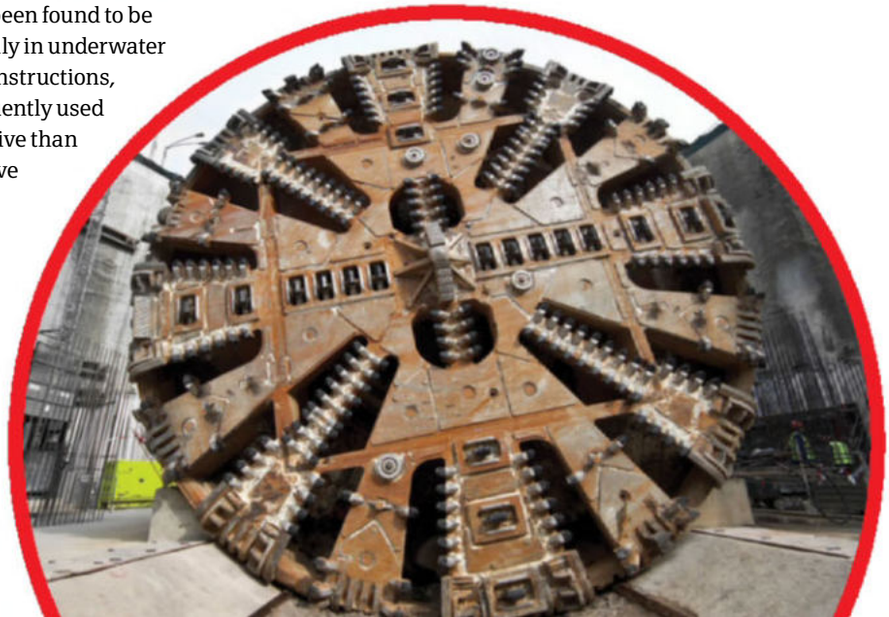


**Road**
Underground roads need to be wide to accommodate high levels of traffic and properly ventilated to avoid fire.

**Rock type**
If the ground is soft rock, standard-digging techniques can be used but in hard rock only blasting with explosives or shielded TBMs will do.

"Mole tunnelling machines [...] are guided by laser beams to punch through the dirt quickly and powerfully"

**Railway**
Tunnel boring machines (TBMs) construct underground railway tunnels by using a rotating cutter with a force equivalent to lifting over 2,900 London taxis.



**RIGHT** A tunnel-boring machine head like the one used on mole tunnelling machines

RECORD BREAKERS
FALSE FACT

# 154km

## THE REAL LONGEST TUNNEL?

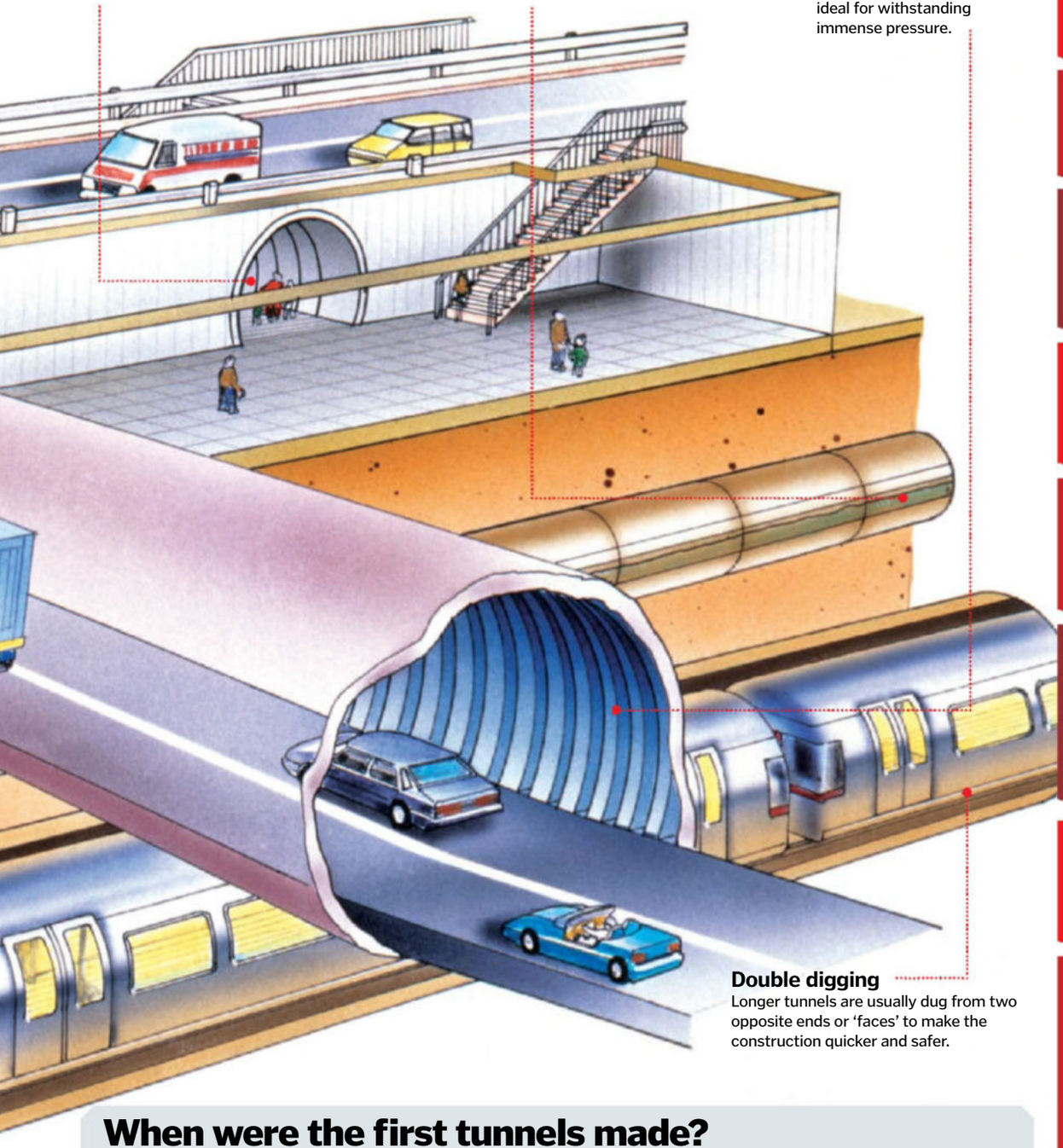
The Thirlmere Aqueduct was constructed in Northwest England in 1925 and would be the longest tunnel in the world if its length was continuous and didn't have gaps in it.

**DID YOU KNOW?** *The TBM 'Bertha' is named after Bertha Knight Landes, the first female mayor of a major US city*

**Pedestrian**
Underpasses are designed to relieve congestion on the streets and can be made quickly as they are only constructed marginally below ground.

**Wastewater**
Cities use huge sewage systems made of tough interlocking concrete segments to ferry waste to out-of-town treatment farms.

**Inverts and crowns**
The bottom half of a tunnel is called the invert while the topside is a crown. An arch is an incredibly strong structure ideal for withstanding immense pressure.



**Double digging**
Longer tunnels are usually dug from two opposite ends or 'faces' to make the construction quicker and safer.

## When were the first tunnels made?

As civilizations prospered and grew, natural obstacles like mountain ranges had to be mined through to gain access to other valleys as well as locating natural resources and precious gems. The first tunnels were built in Ancient Egypt and Babylon and were used primarily for irrigation. Constructions became more ambitious in the Roman era with the Cloaca Maxima in Rome an example of improved engineering. The first railroad tunnel built for US railroads was the Staple Bend Tunnel on the Allegheny Portage Railroad in 1833. Nearly 11,400 cubic metres (402,300 cubic feet) of rock were blasted out to construct it. In the 19th century, tunnels were built using a tunnelling shield first created by Marc Brunel (father of the famous Isambard) in 1825 and improved upon by Peter Barlow and James Greathead in the 1880s. This system would protect miners under a reinforced hood that shielded them from water and rubble. Since the start of the 20th century, huge projects, including many in the Alps such as the Mont Blanc and Arlberg Tunnels, have helped to develop new ventilation and water management techniques.

**23 METRES WIDE**
The Yerba Buena Island tunnel is the largest single-bore tunnel

**15 MILES**
Longest road tunnel in the world is the Lærdal Tunnel

**38 KILOMETRES UNDERWATER**
The Channel Tunnel has the longest undersea portion of any tunnel

**54 KILOMETRES**
The longest rail tunnel is the Seikan Tunnel

**4.9km**
The Fenghuo Mount Tunnel is the highest tunnel on Earth

**600**
tunnels in the Netherlands have been built to help the local endangered animals

**240 METRES BELOW SEA LEVEL**
The Seikan Tunnel is also the deepest rail tunnel

**175 METRES UNDERGROUND**
The Large Hadron Collider in Switzerland

**30 MILLION TONS**
Rock that has been blasted out of the Alps to make the St Gotthard Base Tunnel.


# SAVE RHINOS NOW

## 10% OF OUR PROFITS HELP FIGHT POACHING

**An animal in crisis**
In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

**Make a difference today**
Ol Pejeta is a leading conservancy fighting against this cruelty. It needs more funds so more rangers and surveillance can be deployed on the ground to save rhinos from this horrible treatment.

**Join World of Animals**
World of Animals magazine takes a stand against these atrocities and is proud to be in partnership with the Ol Pejeta Conservancy – 10% of our profits go towards saving rhinos in the fight against poaching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**Check out the AR Drone in action**

www.howitworksdaily.com

**DID YOU KNOW?** *Scientists have managed to 3D print cars, model space probes, jet parts, bones and even human ears*

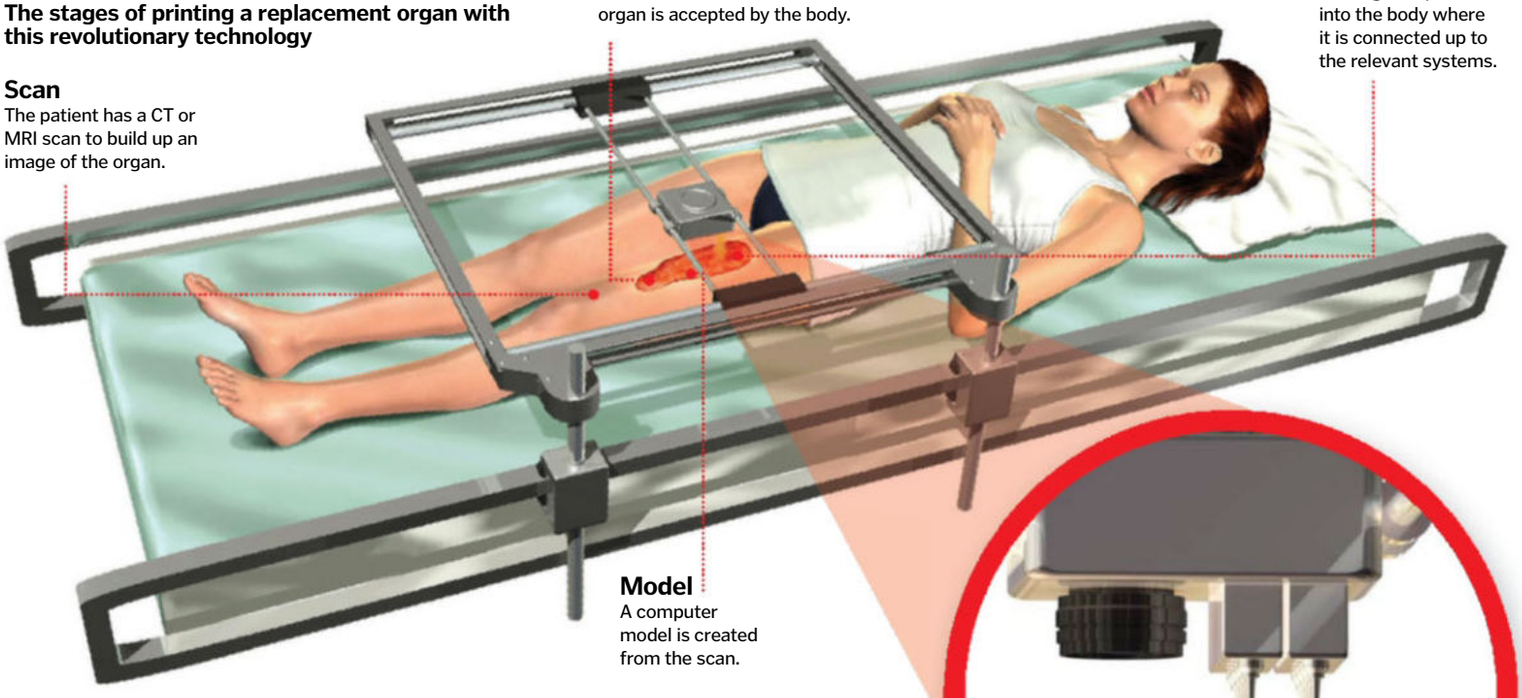
## How to 3D print an organ

**The stages of printing a replacement organ with this revolutionary technology**

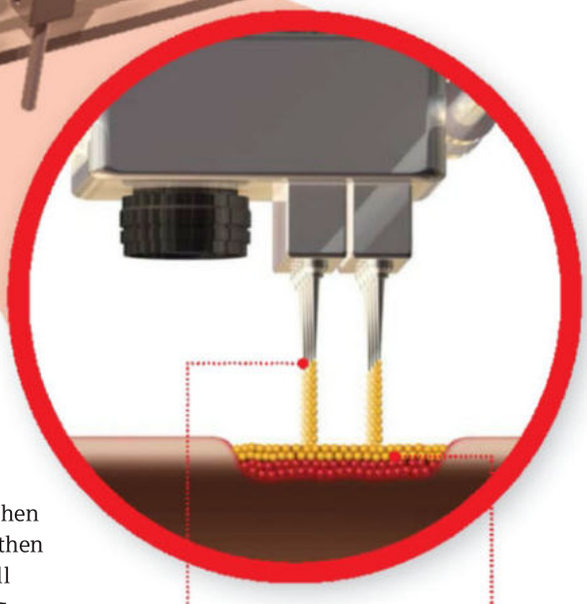
**Scan**
The patient has a CT or MRI scan to build up an image of the organ.

**Acceptance**
Doctors then wait to see if the organ is accepted by the body.

**Implant**
The organ is placed into the body where it is connected up to the relevant systems.



**Model**
A computer model is created from the scan.



**Printing**
The organ is printed using human cells and a sticky gel that binds it together.

**Gel removal**
The gel gets washed away, leaving just the cells in the shape of the organ.

# 3D-printed organs

## The next step in the world of 3D printing

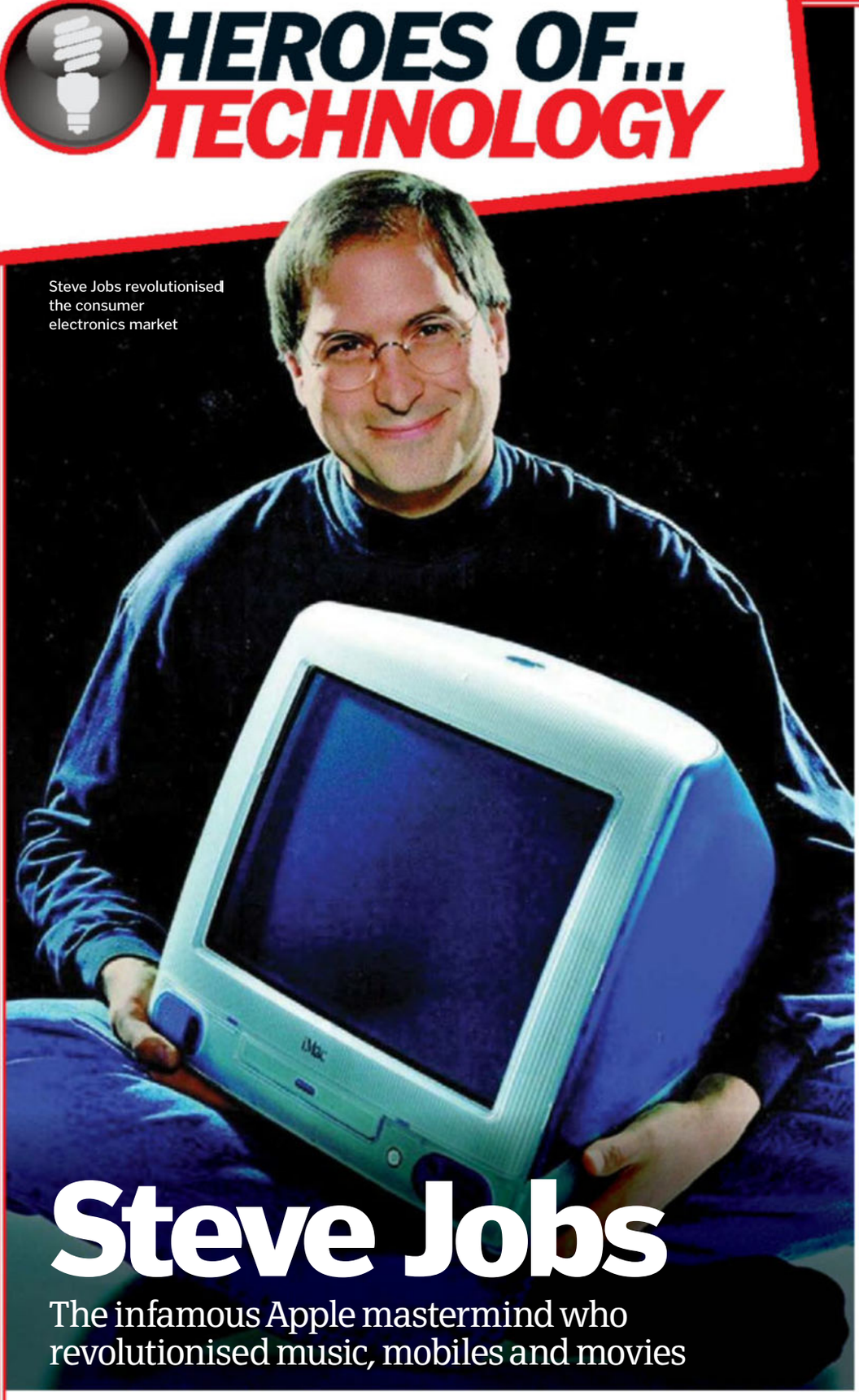
At the turn of the century, printing was limited to words and pictures on a page. Now, in less than two decades, we are on the cusp of being able to print human organs. Patients are sent for a CT or MRI scan that maps out the organ that needs to be printed. A digital model is then created in a computer. The printer uses human cells mixed with a gel to build up a 3D image of the organ. The gel is then removed, leaving just the cells. This would then be implanted into the patient. There are still many challenges to overcome in 3D printing organs, such as creating arteries, veins and capillaries, but the day we can replace a person's liver, kidney or even heart with a 3D-printed organ seems to be creeping ever closer.

# AR Drone 2.0

## The latest generation of personal drones

Until recently, the drone world was the domain of the world's military, but now we are able to use them as our own personal moviemakers. The AR Drone 2.0 is a 380-gram (13.4-ounce) carbon-fibre video drone. Using an app you can download onto your Android or Apple device, you pilot the drone by tilting your smartphone or tablet, guided by the on-board camera.

The HD camera records at 720p, which it sends straight to the smartphone or tablet you're using to pilot the drone. If you really want to channel your inner Tarantino, you can set the drone to Director Mode. This sends it into semi-autonomous mode, providing a stable pan or crane shot. Footage remains steady thanks to a pressure sensor that keeps the drone upright regardless of altitude and winds up to 15 kilometres (nine miles) per hour.



Steve Jobs revolutionised the consumer electronics market

# Steve Jobs

## The infamous Apple mastermind who revolutionised music, mobiles and movies

Steve Jobs was one of the most controversial figures of the late-20th and early-21st century. Though he was criticised for his autocratic leadership, unrelenting perfectionism and greed, his consumer insight enabled him to build one of the planet's most recognisable brands and gather a near-religious following.

Jobs was born in 1955 in San Francisco. He was adopted by Paul and Clara Jobs, a working-class couple living in Silicon Valley. While at high school, he took up a summer job at Hewlett Packard where his passion for technology grew. It was during this time that he met Steve Wozniak, and on graduating the pair began building a computer in his parents' garage. With Wozniak's technical genius and Jobs' innovation, they were able to build a new type of personal computer. The Apple I, which went on sale in 1976, came complete and worked straight out of the box. In the dawn of the personal computing boom, it was an instant success, and sales of the second model skyrocketed. Apple Computer, Inc was born.

But Jobs' prosperity at Apple was short-lived. The Macintosh model failed to take off and three of the six Apple factories were shut down. Jobs' autocratic style of leadership also led to an internal power struggle, and in 1985 he left Apple. Instead, Jobs founded a company called NeXT that built workstations for the higher-education market. He also bought Graphics Group, which made high-end hardware for computer-animated films. Jobs transformed it into a studio, renamed it Pixar, and turned it into one of the biggest names in the film industry.

Meanwhile, Apple was teetering on the brink of bankruptcy. The launch of the much more affordable Windows 95 meant the mouse and

*"With the Mac battling for survival in a Windows world, Jobs decided it was time to take a different direction"*

## The life of Jobs

**Steve Jobs' path from birth to success wasn't straight and easy**

**1955**
Jobs is born to two unmarried students, and adopted by Paul and Clara Jobs.

**1972**
Takes up a job at Atari, a videogame and home computer company, as a technician.

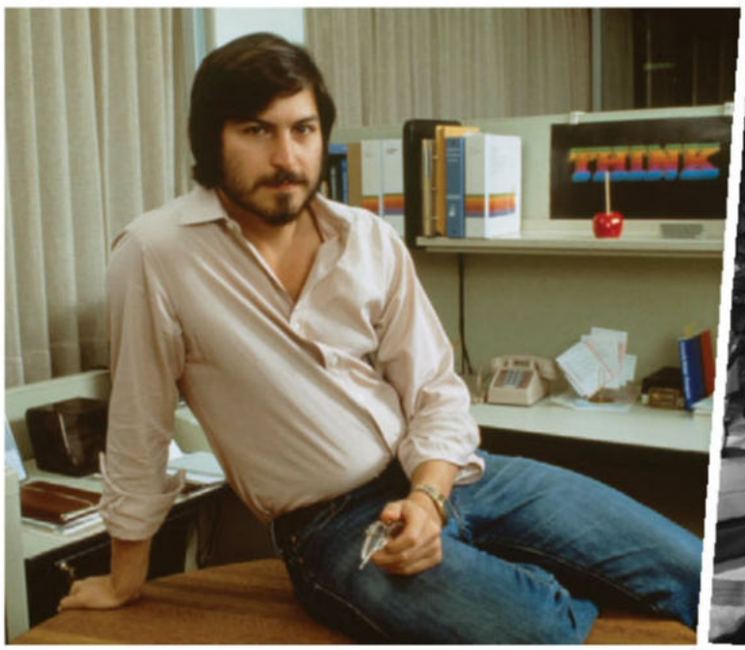
**1974**
Travels to India, where he converts to Buddhism, becomes a vegetarian and experiments with psychedelic drugs.

**1976**
Together with his friend Steve Wozniak, he builds the very first Apple I computer in his parents' garage.

# The big idea

## Why was the iPod so successful?

In 2000, Apple was surviving but not thriving. The release of the iPod in 2001 changed all this. But what made it stand out from all the other MP3 players on the market? First, the iPod was incredibly easy to use. With only five buttons, a click wheel and a simple menu, it was easy to operate and navigate, as well as arguably being the most stylish player on the market. It also did a really good job of integrating the player, the computer and the software, and was Windows-compatible as well. Along with the launch of iTunes, these all equated to an unparalleled success story.




graphical user interface were now industry standards, and Apple's turnover plummeted. Despite this, in 1996 Apple paid more than $400 million for NeXT and Jobs returned to Apple.

With the Mac battling for survival in a Windows world, Jobs decided it was time to take a different direction. In 2001, he unveiled the iPod – a sleek, statement device that met the demand for music on the move and was to become the best-selling portable music player of all time. This was followed by the launch of the iTunes music store in 2003. In 2007, thousands of devoted Applites (the nickname for devoted Apple fans) queued for blocks to get their hands on Jobs' latest brainchild: the iPhone. By 2010, Apple had sold almost 90 million of them.

In October 2011 Jobs died from complications of pancreatic cancer, leaving Apple the second-most valuable company in the world with £50 billion ($80 billion) in the bank. His mark had been well and truly engraved into the company, and remains on the property of millions of people around the world.

**ABOVE LEFT**
A young Steve Jobs in his office at Apple

**ABOVE RIGHT**
Jobs (left) with John Sculley and Steve Wozniak in 1984

# Top 5 facts: Steve Jobs

**1 Fruit influence**
Jobs was on a fruitarian diet when he christened Apple. He had just come back from an apple farm and thought the name sounded "fun, spirited and not intimidating."

**2 Buddhist beliefs?**
He converted to Buddhism after a trip to India, but was criticised throughout his career for his reluctance to produce environmentally sustainable products.

**3 Inner artist**
Jobs briefly attended art school, but dropped out after one term. However, he used the skills he learned there to create Apple's sleek, well-designed products.

**4 Control freak**
As a perfectionist, Jobs insisted on a 'closed system of control', which meant he had control over all aspects of a product from start to finish.

**5 Film credits**
Jobs bought Graphics Group for $5 million in 1986, renamed it Pixar and changed it into an animation studio. He was later credited as an executive producer on the studio's first full-length film, 1995's *Toy Story*.

# In their footsteps...

### Bill Gates

Although a market rival, Jobs and Gates had a close relationship. Gates wrote his first software program at just 13 years old – a version of tic-tac-toe where users played the computer. He went on to study at Harvard, but dropped out to start up his own software company – Micro-Soft. With the hyphen dropped, Microsoft launched its first retail version of Windows in 1985. Two years later, Gates was a billionaire.

### Tim Cook

Cook replaced Jobs as Apple CEO in August 2011. After studying industrial engineering and business administration, Cook took up a job at IBM where he later became the fulfilment director. He joined Apple in 1998, when the company was seeing declining profits. Cook was partly responsible for Apple's U-turn in success, with the company reporting profits less than a year later.

**1977**
The Apple II is a roaring success. Apple Computer, Inc is born.

**1985/6**
Jobs leaves Apple, founds NeXT and forms Pixar out of a computer-hardware firm.


**1996**
Returns to Apple as an advisor and steers it away from bankruptcy.

**2001**
The iPod is launched and becomes the most successful portable music player of all time.

**2007**
Jobs introduces the iPhone. Shops report shortages within an hour of it going on sale.

**2011**
Jobs dies of pancreatic cancer, aged 56.

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RECORD BREAKERS
ROWING FEAT

# 6 HUNDRED

## MOST ROWERS IN 24 HOURS

On 8 March 2013, 600 people rowed 500m (1,640ft) each in 24 hours at Mercyhurst University in Pennsylvania, USA.

**DID YOU KNOW?** *Sir Steve Redgrave produced up to 500W during his Olympics races, enough to power a PC for six hours*

# Gore-Tex

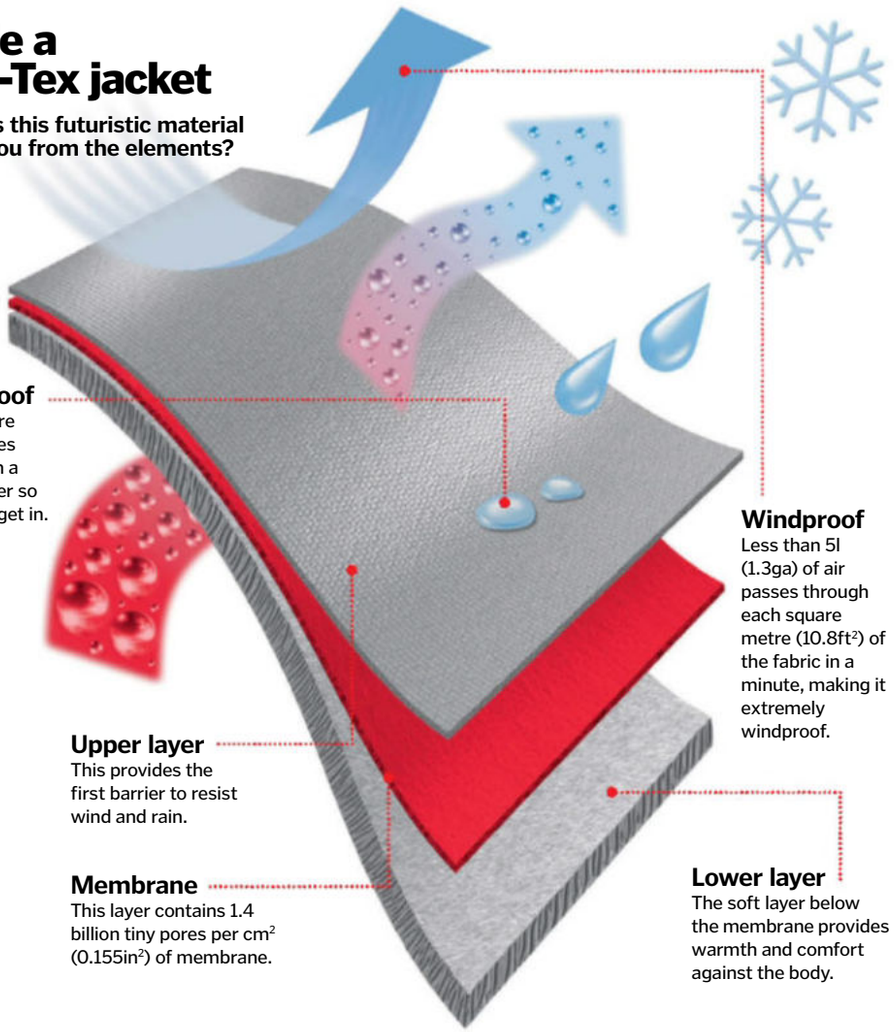
## The science behind this waterproof and windproof material

Gore-Tex clothing is a favourite among hikers because it keeps Mother Nature at bay. Unlike nylon – which is waterproof but traps sweat – Gore-Tex is a 'breathable' fabric. It has all to do with a thin membrane embedded in the garment where there are 1.4 billion pores per square centimetre (0.155 square inches). As each pore is larger than a water vapour molecule, sweat is able to escape through the fabric. These tiny pores also massively reduce the amount of wind that can get in.

This doesn't stop it being waterproof, however. Even though each pore is bigger than a water vapour molecule, it is smaller than a liquid water molecule, so rain is unable to get through to your body.

### Inside a Gore-Tex jacket

**How does this futuristic material protect you from the elements?**



**Waterproof**
The pores are 20,000 times smaller than a drop of water so no rain can get in.

**Windproof**
Less than 5l (1.3ga) of air passes through each square metre (10.8ft²) of the fabric in a minute, making it extremely windproof.

**Upper layer**
This provides the first barrier to resist wind and rain.

**Membrane**
This layer contains 1.4 billion tiny pores per cm² (0.155in²) of membrane.

**Lower layer**
The soft layer below the membrane provides warmth and comfort against the body.

# How rowing machines work

## The first step to becoming the new Sir Steve Redgrave

Rowing machines are a staple of the gym, but how do they work and what does that lever on the side actually do? The entire system of indoor rowing works on the principle of resistance. When you pull the chain back it spins a flywheel inside the housing. As you return to the starting position the chain winds back round, ready for another tug on the flywheel.

The lever on the side is called the damper and this affects how much air is allowed into the system. When the setting is higher, more air is able to get in, making the flywheel harder to rotate as it's battling against more air resistance. Even when you're on the return stroke, the air is still working against you, slowing the flywheel down so it takes more effort to pull it back again.

# END OF OUR SUN

## The lifecycle of our nearest star

Every star that exists today, including our very own Sun, will die. Stars live a long time – from millions to trillions of years – but when it comes time for them to expire, they do so in one of two ways; either beautifully or dramatically.

We know stars produce energy and heat by nuclear fusion reactions of hydrogen nuclei in their cores that, through two main processes, create helium. The energy generated from that radiates outward, balancing the force of gravity that tries to cause the star to collapse upon itself. It is when this hydrogen begins to run out that a star enters old age.

A star's ultimate fate depends on its mass. We know that a star the mass of the Sun will go out the beautiful way. Our Sun formed 4.6 billion years ago and has been using hydrogen all of that time, but the Sun is so massive that it still retains enough hydrogen to keep going for another five billion years. At that time, the hydrogen in the Sun's core will run out and stop producing energy. The core will begin to contract as gravity takes over, the temperature and pressure rising, at which point it will become hot enough for helium to step in for hydrogen and continue the nuclear reactions. Meanwhile, hydrogen in the outer layers of the Sun will ignite in fusion reactions and it will bloat into a huge red giant that will engulf and destroy little Mercury, Venus and possibly Earth and Mars too.

A few million years later, the outer layers of gas from the red giant are cast off and blossom into what is called a planetary nebula. In images taken by the Hubble Space Telescope and the Spitzer Space Telescope, the latter of which can peer in infrared through the dust of the nebula, these look like beautiful butterfly-shaped clouds of colourful gas. By studying these nebulas we can learn more about the fate of our own Sun and planets. Gradually the nebula disperses but the core of the star remains. About the size of Earth, the core no longer produces energy from nuclear reactions, but is tremendously hot, up to 100,000 degrees Celsius (180,000 degrees Fahrenheit). We call this a white dwarf.

## 5 TOP FACTS PLANETARY NEBULAS

**1 They're short-lived**
Planetary nebulas are a fleeting but dramatic final phase in a star's life, lasting for only 10,000 years after the death of the star.

**2 They're relatively rare**
Only 3,000 are known to exist in our galaxy, a small amount compared to the number of stars, but it is their short life span that results in there being so few at any one time.

**3 They're hot**
The white dwarf can heat planetary nebula up to about 1mn°C (1.8mn°F) at the centre, 25,000°C (45,000°F) in the middle and 10,000°C (18,000°F) near the edges.

**4 They have odd shapes**
A typical planetary nebula expands to about a light year across and continues to expand beyond this size, but it grows less dense and eventually fades away.

**5 They have odd shapes**
Planetary nebulas come in all shapes, from rings and cylinders to twisting twin lobes, possibly sculpted by the presence of an unseen companion star.

**DID YOU KNOW?** *The last supernova to be seen with the naked eye to explode in our galaxy was in 1604*

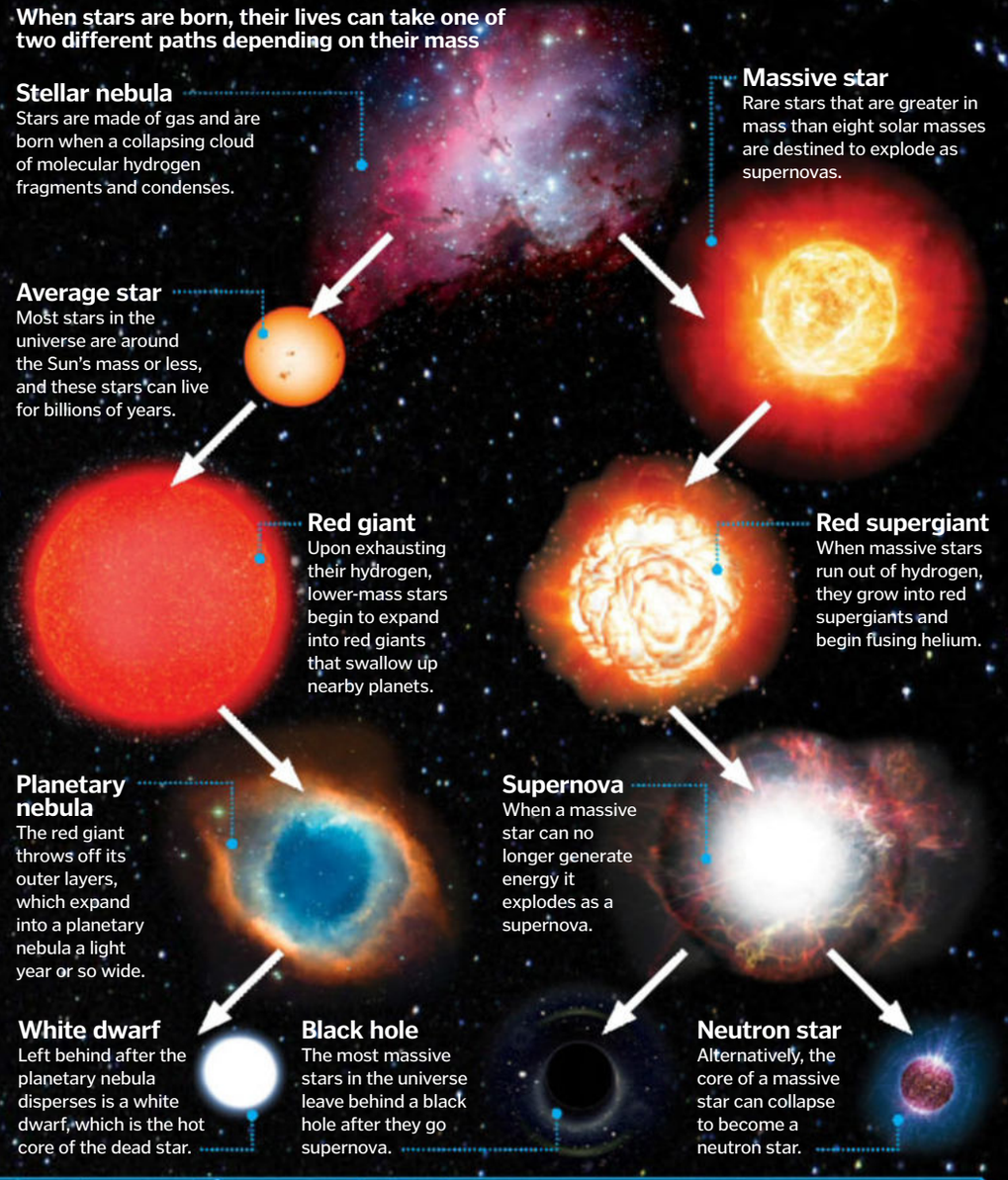
Some white dwarfs in close-orbiting binary systems are faced with eventual complete destruction. Sometimes they will siphon gas from their companion star, growing more massive with the stolen material until they become so massive – more than 1.44 times the mass of the Sun, that they explode as a so-called Type Ia supernova. Alternatively, two white dwarfs in a binary system can collide with one another, also resulting in the creation of a supernova.

However, not all supernovas are a result of white dwarfs. The stars that go the opposite evolutionary paths to the white dwarfs meet their end in a relatively more sudden and just as cataclysmic manner. Those stars are the ones that become more massive than eight times the mass of the Sun collapse when they run out of hydrogen, causing an internal shock wave that essentially rips the star apart. These supernovas – designated as both Type Ib and Type II supernovas – leave either neutron stars or black holes as remnants from their demise.

Dying stars produce all the known heavy elements in the universe through their nuclear reactions and they spread them into interstellar space when they die. Planetary nebulas, for example, produce much of the carbon, oxygen and nitrogen found in the universe. Supernovas release all the heavier elements, either forged inside the star or through the violence of the explosion. This material is gradually recycled through molecular gas clouds that are forming the next generation of stars. The elements that made Earth and everything around us, even our bodies, were originally created in a distant star that died catastrophically billions of years ago.

# THE LIFE CYCLE OF A STAR

**When stars are born, their lives can take one of two different paths depending on their mass**



**Stellar nebula**
Stars are made of gas and are born when a collapsing cloud of molecular hydrogen fragments and condenses.

**Massive star**
Rare stars that are greater in mass than eight solar masses are destined to explode as supernovas.

**Average star**
Most stars in the universe are around the Sun's mass or less, and these stars can live for billions of years.

**Red giant**
Upon exhausting their hydrogen, lower-mass stars begin to expand into red giants that swallow up nearby planets.

**Red supergiant**
When massive stars run out of hydrogen, they grow into red supergiants and begin fusing helium.

**Planetary nebula**
The red giant throws off its outer layers, which expand into a planetary nebula a light year or so wide.

**Supernova**
When a massive star can no longer generate energy it explodes as a supernova.

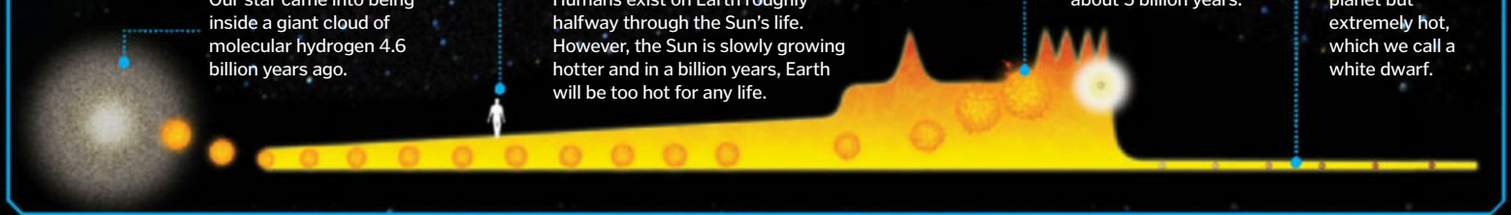
**White dwarf**
Left behind after the planetary nebula disperses is a white dwarf, which is the hot core of the dead star.

**Black hole**
The most massive stars in the universe leave behind a black hole after they go supernova.

**Neutron star**
Alternatively, the core of a massive star can collapse to become a neutron star.

# Timeline of a Sun's life

Our Sun's life will span around 10 billion years before it evolves to become a white dwarf. Over its life it will grow brighter and hotter before starting to run out of hydrogen, expanding into a red giant that will be 200 to 300 million kilometres (124 to 186 million miles) in diameter and swallow up the inner planets. This red giant will evaporate into a planetary nebula, leaving behind an inert but white-hot white dwarf.



**Birth of the Sun**
Our star came into being inside a giant cloud of molecular hydrogen 4.6 billion years ago.

**Middle age**
Humans exist on Earth roughly halfway through the Sun's life. However, the Sun is slowly growing hotter and in a billion years, Earth will be too hot for any life.

**Red giant**
As the Sun ages it uses up hydrogen and when it runs out it will evolve into a red giant in about 5 billion years.

**White dwarf**
The red giant leaves behind a compact core only the size of a planet but extremely hot, which we call a white dwarf.

"As the temperature rises, carbon begins to fuse into neon, then oxygen and then silicon"

# SUPERNOVA

**When massive stars die they produce some of the biggest bangs in the universe**

The brightest stars in the universe are also the ones that shine for the shortest time. A massive star, which unleashes a brilliant torrent of light, uses up its hydrogen so fast that it only lives for a few million years, compared to the 10-billion-year lifetime of our Sun, a much smaller star. This is because a massive star has so much mass that it takes a lot more energy to prevent it from collapsing under its own gravity, so it uses up its hydrogen much faster.

When this star runs out of hydrogen, the core contracts a little and the temperature rises enough for the star, in rapid-fire succession, to begin fusing helium, which produces carbon. As the temperature rises, carbon begins to fuse into neon, then oxygen and then silicon, creating shells of these elements like onion layers inside the star until the core contains only iron. At this point, the star cannot process iron any further, and so energy production suddenly stops dead and the star collapses in on itself.

In a matter of a few fleeting seconds, the star's collapsing outer layers rebound off the core, which becomes incredibly compressed. The resulting outward-bound shock wave tears the star apart in a catastrophic supernova, which can produce more energy in an instant than the Sun can in its entire lifetime. It is so bright it can be seen across the entire universe – astronomers regularly discover supernovas in other galaxies, but the last supernova to be seen in our galaxy exploded in 1604.

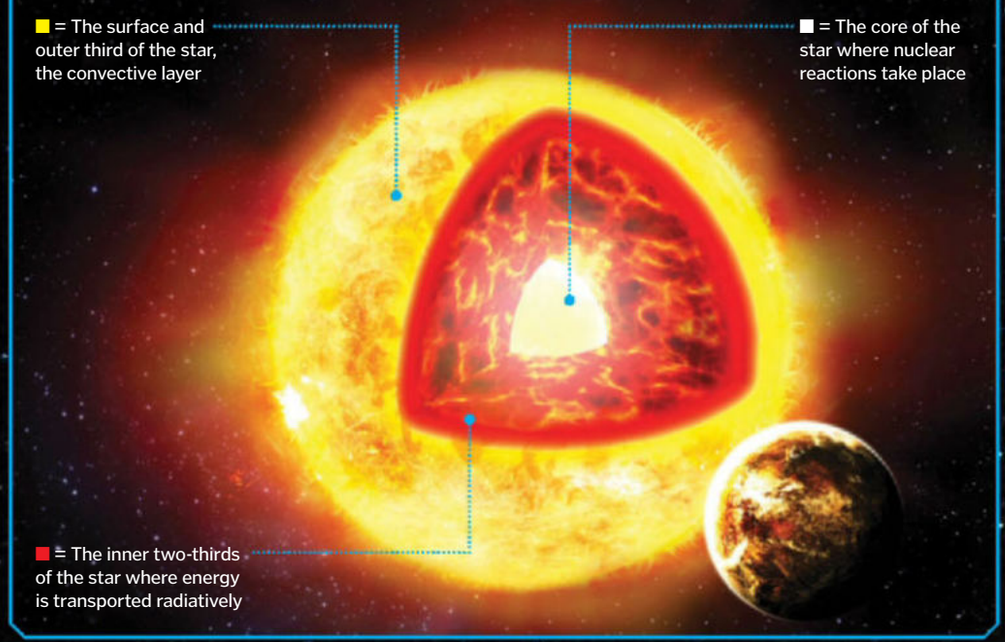
The debris from this – literally – astronomical explosion becomes a gaseous supernova remnant that, like a planetary nebula, disperses into space. The most famous supernova remnant is the Crab Nebula in the constellation Taurus, which is the debris of a star that exploded in 1054 CE. Meanwhile, the core is so compressed that positive protons and negative electrons are forced together to produce neutral neutrons – a neutron star that's only about ten kilometres (6.2 miles) across. In the most extreme cases with the most massive stars, the core can compress even further to become a black hole, consuming planets, other nearby stars and even light itself in the process.

## Stellar remnant

When a star explodes it spews its guts out into interstellar space at speeds of around ten per cent of the speed of light. We see the debris as a nebula. Shock waves ripple through the nebula as the expanding material collides with shells of gas and dust that had been ejected by the star during previous outbursts. This can heat the gas in the remnant so that it becomes so hot it produces plenty of X-rays. Gradually, the remnant cools and merges with the diffused, spread out gas in interstellar space. The remnant is rich with heavy elements from everything from calcium to silver and gold. Eventually, gravitational forces sweep up the material from the supernova into a new star-forming nebula, starting the cycle again.

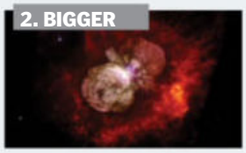
## What are stars made of?

When a star is born, it is made from about three-quarters hydrogen and almost a quarter helium, with only trace amounts of other gases. It is hottest within its core – the Sun's core, for example, is a blistering 15 million degrees Celsius (27 million degrees Fahrenheit). Here the nuclear fusion reactions take place. Stars the mass of the Sun mainly do this through the proton-proton chain reaction, where two hydrogen atoms fuse into a helium-2 isotope that decays into deuterium, which then fuses with another hydrogen atom into helium-3. Via a further series of reactions, helium-3 can be transformed into helium-4. Gradually the core fills up with this helium 'ash' while the energy is radiated away through the inner two-thirds of the star, before being transported to the surface by convection currents. It can take millions of years for this energy to eventually reach the surface!



1. BIG

**Betelgeuse**
This red supergiant has a mass between ten and 20 times the Sun. When it goes supernova it could create a spinning neutron star called a pulsar.



2. BIGGER

**Eta Carinae**
A star system of 100 solar masses like Eta Carinae is very rare – only a handful are known in the galaxy. When they explode they leave behind a black hole.

3. BIGGEST

**R136a1**
The most massive known star is R136a1, in the Large Magellanic Cloud. When it explodes it will do so in a so-called gamma-ray burst, leaving behind a black hole.

**DID YOU KNOW?** *Neutron stars are so dense that a teaspoon of their material would weigh more than everyone on Earth*

# STAGES OF A SUPERNOVA

**The life and death of a massive star**

**1 Birth**
Like all stars, massive stars form in collapsing clouds of gas. However, they are much rarer than smaller stars.

**2 Growing big**
Nobody is certain why massive stars are able to grow so big, but magnetic fields may be able to slow the collapse, allowing more gas to pile on.

**3 Double stars**
Double stars are more common than single stars and many massive stars also come with giant companions.

**4 Blue stars**
The most massive stars are the hottest and they shine a brilliant hot blue.

**5 Explosion**
When a massive star can no longer generate energy, it explodes as a supernova.

**6 Dusty debris**
So much dust is created in supernova explosions that 200,000 planets the size of Earth could be made from it.

**7 Supernova remnant**
The supernova remnant is a cloud of gas and dust rich in all kinds of heavy elements, to be recycled into new stars and planets.

**8 Cosmic rays**
The magnetic fields in supernova remnants are able to accelerate charged particles to almost the speed of light, which travel across the universe as cosmic rays.

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## THE STATS JUPITER

**140,000km** AVERAGE DIAMETER

16,500km GREAT RED SPOT SIZE

**10** HOURS IN A DAY

-145°C LOWEST TEMPERATURE

AVERAGE WIND SPEED **360km/h**

HIGHEST TEMPERATURE 35,500°C

**DID YOU KNOW?** *17th-century astronomer Giovanni Cassini called the Great Red Spot the "Eye of Jupiter"*

# Weather on Jupiter

## The forecast is raging storms and swirling winds

If you've ever moaned about the weather, then you can count yourself lucky that you don't live on Jupiter. The majority of the planet is formed of hydrogen and helium gases. The clouds, however, are made up of ammonia ice crystals.

The temperature range on Jupiter is pretty incredible. The clouds that hover above the surface of the planet are a freezing -145 degrees Celsius (-229 degrees Fahrenheit), but as you move closer to the core it reaches a scorching 35,000 degrees Celsius (63,000 degrees Fahrenheit). And if that doesn't sound quite bad enough, then the weather conditions on the surface of the planet are almost guaranteed to put you off.

We spoke to expert Pedram Hassanzadeh, an Environmental Fellow at Harvard University: "The atmosphere of Jupiter has two prominent visible features", he explains. "These are strong winds that form multiple jets of alternating direction between the equator and the poles, and hundreds of hurricane-like swirling winds known as vortices. The average speed of the jets can be more than 360 kilometres (224 miles) per hour. For comparison, Earth has two prominent eastward jets in each hemisphere and their average speed is about 100 kilometres (62 miles) per hour."

If, having seen the wild temperature changes, the mind-boggling winds and dramatic tornadoes, you are still keen to visit Jupiter, Hassanzadeh has one more word of advice for any potential tourists: "Jupiter does not have a solid surface, which would make life on the planet kind of hard."

### The Great Red Spot

One of the best-known features of Jupiter, apart from its size, is the Great Red Spot. First recorded in 1831 and consistently observed for more than 100 years, the weather system measures about 16,500 x 14,000 kilometres (10,250 x 8,700 miles). Hassanzadeh explains what the Great Red Spot actually is: "It consists of strong swirling winds with a maximum speed of 700 kilometres (435 miles) per hour. It's not clear how the Great Red Spot was created, but vortices are common in rapidly rotating environments such as the atmosphere of the gas giants."

The Great Red Spot is notable as it has been raging for centuries, much longer than any other similar space tornadoes. However, Hassanzadeh has a theory as to how it has kept going for so long: "It has been speculated that the Great Red Spot has survived by extracting potential energy from the atmosphere and the kinetic energy of the jets, along with absorbing smaller vortices."

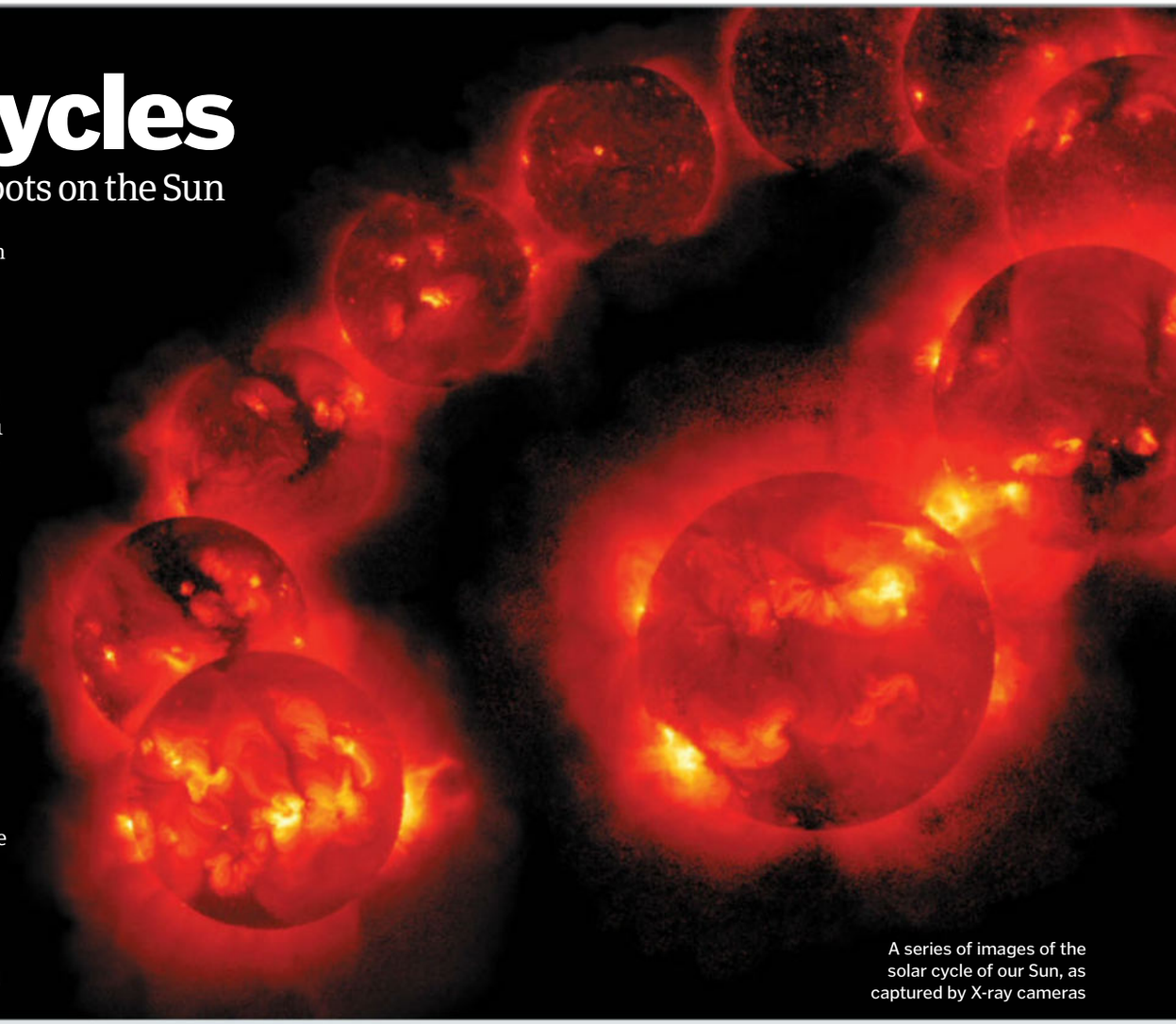
"Y dwarfs belong to a larger family called brown dwarfs or 'failed stars' as Dr Sarah Casewell calls them"

# Solar cycles

## The rise and fall of spots on the Sun

A solar cycle is a change in the Sun's activity and appearance. Solar cycles occur due to the magnetic field of the Sun twisting around as it rotates – north becomes south and vice versa – approximately every 11 years. At the low point of the cycle, there are very few sunspots and solar flares. However, during the peak, these become visible.

Sunspots occur in patches of the Sun's surface where the magnetic field is stronger. This stops hot gas rising to the surface, so sunspots are around 1,500 degrees Celsius (2,732 degrees Fahrenheit) cooler than the surrounding area. Solar flares are created when the magnetic fields of the Sun cross over. These tangled lines can cause the release of enormous amounts of energy, sending gas and radiation speeding towards Earth at over 10 million degrees Celsius (18 million degrees Fahrenheit).



A series of images of the solar cycle of our Sun, as captured by X-ray cameras

An artist's impression of a Y dwarf – the coldest star-like bodies in space

# Y dwarfs

## Find out why these failed stars are chilling in space

Dr Sarah Casewell

Usually when a star begins to die, it converts its hydrogen into helium, giving off an incredible amount of heat and light, like our Sun. However, scattered around the universe are relatively small – but still Jupiter-sized – stars that haven't quite been able to muster up enough energy to perform this vital conversion. These stars are called Y dwarfs, and they are the coldest star-like bodies in space by a considerable margin, with some having temperatures lower than the human body.

Y dwarfs belong to a larger family called brown dwarfs or "failed stars", as Dr Sarah Caswell from the University of Leicester calls them. "While other dwarfs and stars give off heat by converting hydrogen to helium, brown dwarfs can't," Dr Casewell explains. "There are three classes of brown dwarf, the coldest of which is Y dwarfs, which are made up of mostly methane gas. At -50 degrees Celsius (-58 degrees Fahrenheit), they are some of the coldest bodies in the galaxy."

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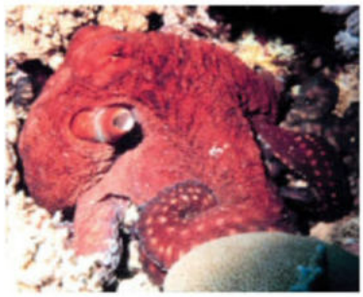


# THE WORLD'S SMARTEST ANIMALS

## Discover fascinating facts about some of the most intelligent animals on Earth




Although humans don't top the food chain, what we lack in physical ability we certainly make up for in mind. But that's not to say we're the only smart animals on the planet. Apes have long been considered our closest living relatives since we share over 90 per cent of their DNA, but we're also surprisingly similar in the intellectual stakes to other species too.

However, judging animal intelligence is not as easy as getting them to sit a multiple-choice exam. In fact, scientists have spent decades devising methods in order to weed out the brainless from the brainy. Researchers will spend years in the wild observing a species' natural behaviour in order to get a better insight into how they learn, solve problems and make decisions. Combining that with controlled lab testing methods, we're finally getting a better understanding of what animals are capable of.

Many animals, including domesticated pets, display cleverness and a desire to learn, but a small handful of species really outshine others when it comes to being truly intelligent. For example, the ability to memorise and recall past events in order to make decisions that will affect the present and future is found only in some of the very smartest animals on Earth. Join us in this feature as we uncover the facts about eight of the most intelligent creatures. From land mammals to marine life, you'll be surprised by how smart these animals really are and how similar they are to us.

**1. LONG**

**Apes**
Primates have a human-like long-term memory and are able to recall past experiences to help solve problems in their environment.

**2. LONGER**

**Elephants**
Elephants remember their relatives and are able to recognise skeletal remains of their peers long after they have died.

**3. LONGEST**

**Dolphins**
Dolphins have an impressive long-term memory that means they're able to recognise a call from a dolphin they have not had contact with for decades!

**DID YOU KNOW?** *Gorillas in the Republic of the Congo were observed using large sticks to test the depth of swamp water*

# GREAT APE

## Decision maker

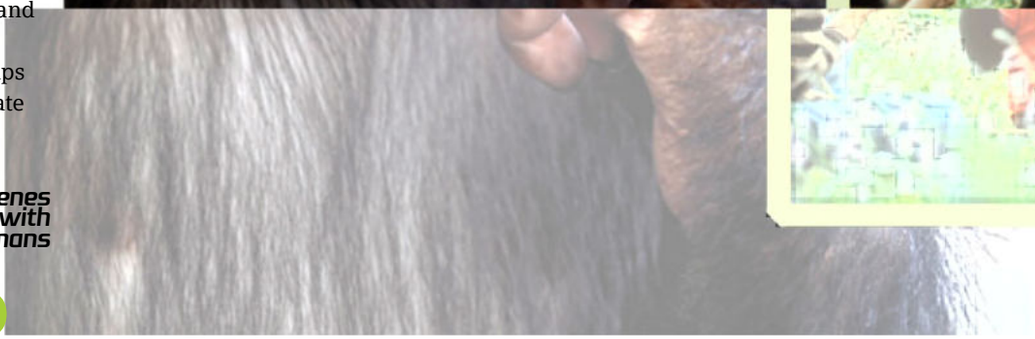
Apes are not quite ready to take over the planet, but they are certainly among the most intelligent animals on Earth. In particular, chimpanzees have been subject to numerous research projects over the years to discover more about their intellectual similarities to humans. Observations have shown these brainiacs are capable of solving complex problems, are adept at decision making and will even make and use tools in the wild to help forage for food. They also have an impressive memory and are able to recognise other chimps and humans they have not seen for several years. In captivity, chimps have been taught to communicate and convey ideas using sign language and lexigrams.

**99%** *Chimp genes shared with humans*

## Talking apes

### How sign language helps us communicate with apes

In 1967, a chimpanzee named Washoe became the subject of cognitive research. Allen and Beatrix Gardner aimed to discover whether chimps could master American sign language (ASL), after previous attempts to teach vocal languages to chimps had failed. To teach sign language to Washoe, they raised her in the same way as a human child and avoided verbal communication. Washoe eventually mastered around 130 signs and she also passed her skills onto her son Loulis. Since the experiment, many other chimps have been taught to use sign language and lexigrams as a way of communicating with humans.



# PIG

## Fast learner

Pigs are one of the most misunderstood species on Earth. Despite their appearance, these smart swines are clean animals that have proven through various scientific studies to be as smart as a three-year-old child! They are impressively fast learners who can respond to their own name, as well as be trained to perform various tasks and tricks, including playing video games.

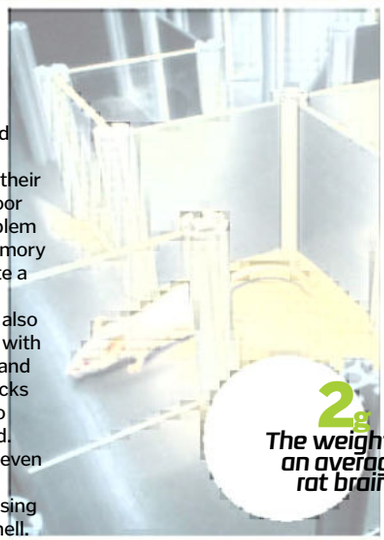
Pigs are also incredibly social animals that communicate with one another using a range of different grunts and squeals – sows will even sing to their young when nursing. What's more, they have excellent long-term memory and a very good sense of direction, so are able to memorise where food is located and how to get home even from miles away.

**30** *Number of different pigs a pig can recognise*

# RAT

## Logical thinkers

Rats are highly intelligent and have been used in scientific research for decades due to their learning ability. They have poor eyesight but are natural problem solvers with an excellent memory that enables them to navigate a route to food without ever forgetting the way. They are also very social and bond quickly with their own kind and humans, and can be trained to perform tricks as well as learn to respond to their own names when called. Gambian pouched rats have even been trained to successfully detect land mines in Africa using their heightened sense of smell.



**2g** *The weight of an average rat brain*

*"We do share intellectual similarities with many animals, not just our closest living relative, the chimpanzee"*

Observation and scientific research have been key to unearthing some fascinating facts about the animals we share our planet with. For centuries, scientists have sought to learn more about animal intelligence in order to determine how we differ as a species. As humans we're set apart from others in the animal kingdom thanks to our advanced thought processes. We're able to retrieve and combine knowledge and information in order to continually gain a new understanding of the world around us, which means we're adept to complex problem solving and can adapt quickly to new surroundings. Although it's been proven that we're all wired differently, we do share some intellectual similarities with many animals and not just our closest living relative, the chimpanzee.

Studying animal intelligence is no simple task, however. It's known scientifically as animal cognition – the study of the mental capacity of animals. Cognition is a term used to describe all mental abilities related to knowledge and takes into account things such as: attention, memory, judgement, comprehension, reasoning, problem solving, decision-making and language. In order to test an animal's cognition, researchers look for evidence comparable to a human's mental process when observing a species. Intelligence is largely evident in animals that display natural decision-making and problem solving abilities

# CROW

**7**
*The number crows can count up to*

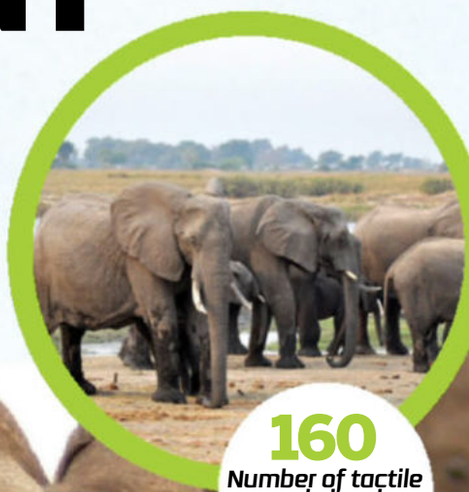
## Cunning planner

Crows are by no means bird-brained; they are in fact cunning and innovative animals that have adapted expertly to their environment. In urban towns and cities, for instance, crows have been observed positioning nuts on the road and waiting for passing cars to crack their tough shells, they'll even wait for a red light before retrieving the snack! What's more, they have a fantastic memory and have been proven to remember human faces and even hold grudges. Crows will also communicate and play tricks on one another in order to hide food they plan to store.

# ELEPHANT

## Giant genius

Elephants are said to never forget. While that may be true, their long-term memory is not the only thing that makes these gentle giants so clever. Scientific observations have proved elephants are also cultured, self-aware and adept to solving problems. In fact, they will use tools in their environment to help them reach food and even coordinate their efforts. Recent research has also shown that elephants are able to tell some human languages apart, and they are able to grasp a person's age, gender and whether they're a threat based on their voice. Elephants in captivity have also displayed an interest in music and some even engage in art with a clear understanding of colour!



**160**
*Number of tactile and visual signals used by elephants*

## 5 TOP FACTS OUTSMARTING HUMANS

**Direction**
**1** While we rely on sat-navs on long journeys, some animals can do so with no assistance. Homing pigeons can identify their geographical position by sensing the Earth's magnetic field!

**Smell**
**2** Most animals have a better sense of smell than us. Elephants can recognise the scent of up to 30 absent family members and can work out their rough location based on the tracks left behind.

**Memory**
**3** Chimps can outsmart us when it comes to memory games, as they have a photographic memory. In tests, young chimps could beat human adults at recalling a sequence of numbers.

**Reproduction**
**4** A species of female ants in the Amazon have developed the ability to reproduce via cloning, which means the number of females able to reproduce each generation is doubled.

**Hearing**
**5** Luckily we don't rely solely on our hearing sense to survive. Animals such as owls can pinpoint the position of sound sources in the dark night in less than 0.01 of a second.

**DID YOU KNOW?** *Octopuses sometimes use coconut shells as a shield to hide from potential predators*

# DOLPHIN

### *Creative*

It's no secret that dolphins are the most intelligent animals in the ocean. Like humans, they are self-aware and learn as individuals who can then educate others based on their own experiences. Passing knowledge between generations means dolphins create certain behaviours unique within their social groups. They are also creative thinkers and especially so when it comes to play and foraging for food. In the wild, dolphins have been known to partake in games of catch using things found in their environment, such as seaweed. They also have a strong memory and a sophisticated language that helps them to communicate with one another.

**30 YEARS**
*Dolphins can remember each other after decades apart*

in the wild, for example: when searching for food, avoiding predators, navigating their environment and seeking shelter. Many other factors are also taken into account when researching animal intelligence, especially in a lab environment. These include animal conditioning and learning, natural behaviour, ecology and even psychology.

Self-awareness in animals is also considered a good indication of intelligence. In humans self-awareness is described as a conscious knowledge of your own feelings, character and how others may perceive you. Naturally, this is hard to test in animals, as there's no direct way to measure their emotions. Scientists therefore perform what's known as the mirror test. The mirror test gauges an animal's self-awareness by determining whether the animal is able to recognise its own reflection in the mirror as an image of itself. To measure this successfully the animal is first marked by a coloured dye; if the animal reacts in a way that shows it's aware the dye is located on itself and not the mirror, the animal is considered to be self-aware. Very few animals have actually passed the test but species that have include chimps, orangutans, dolphins and elephants.

Animals tend to learn largely by conditioning as they form an association between an action and reward, such as food. This is evident in the wild, as an animal will seek resources in ways that have been successful before. This type of positive reinforcement can also be replicated in lab conditions in order to determine if new behaviours, that are not necessarily natural to the animal in the wild, can be learnt.

Young animals that are raised within a family group, such as dolphins and elephants, also learn and replicate behaviours that they witness. This is known as observational learning, and for animals that have unique cultures it's a way that skills, such as using tools, are passed down to younger generations. Interestingly, dolphins are also known to be able to teach others based on their own personal experiences. For example, a bottlenose dolphin that spent three weeks in captivity was trained to perform a tail-walk trick. Once released back into the wild it's believed to have passed this knowledge on to the other wild dolphins in its pod.

**285**
*Number of squirrel species*

# SQUIRREL

### *Deceiving stasher*

These clever critters are pretty deceptive when it comes to protecting their stash of food and will fool potential thieves by pretending to hide food when they know they're being watched. Squirrels also have an impressive memory recall and are able to plan ahead for the winter months by concealing food around the forest that they can locate months later. What's more, squirrels have been scientifically proven to learn behaviours from others, which makes them pretty smart. Squirrels in California have even been observed covering themselves in the scent of rattlesnakes to ward off predators.

**3**
*The number of hearts an octopus has*

# OCTOPUS

### *Problem solver*

Octopuses are pretty skilled problem solvers. For many years, these flexible invertebrates were overlooked when it came to intelligence, however, scientific research has proven them to be quite astute. In fact, octopuses have both short and long-term memory and have been trained in experiments to tell the difference between shapes and patterns. They are also able to problem solve their way out of confined spaces, navigate through mazes and skilfully open jars that contain food.

"All jellyfish are renowned for their sting, and the lion's mane's is pretty potent"

# How do hummingbirds hover?

## This remarkable little bird can eat twice its body weight in nectar

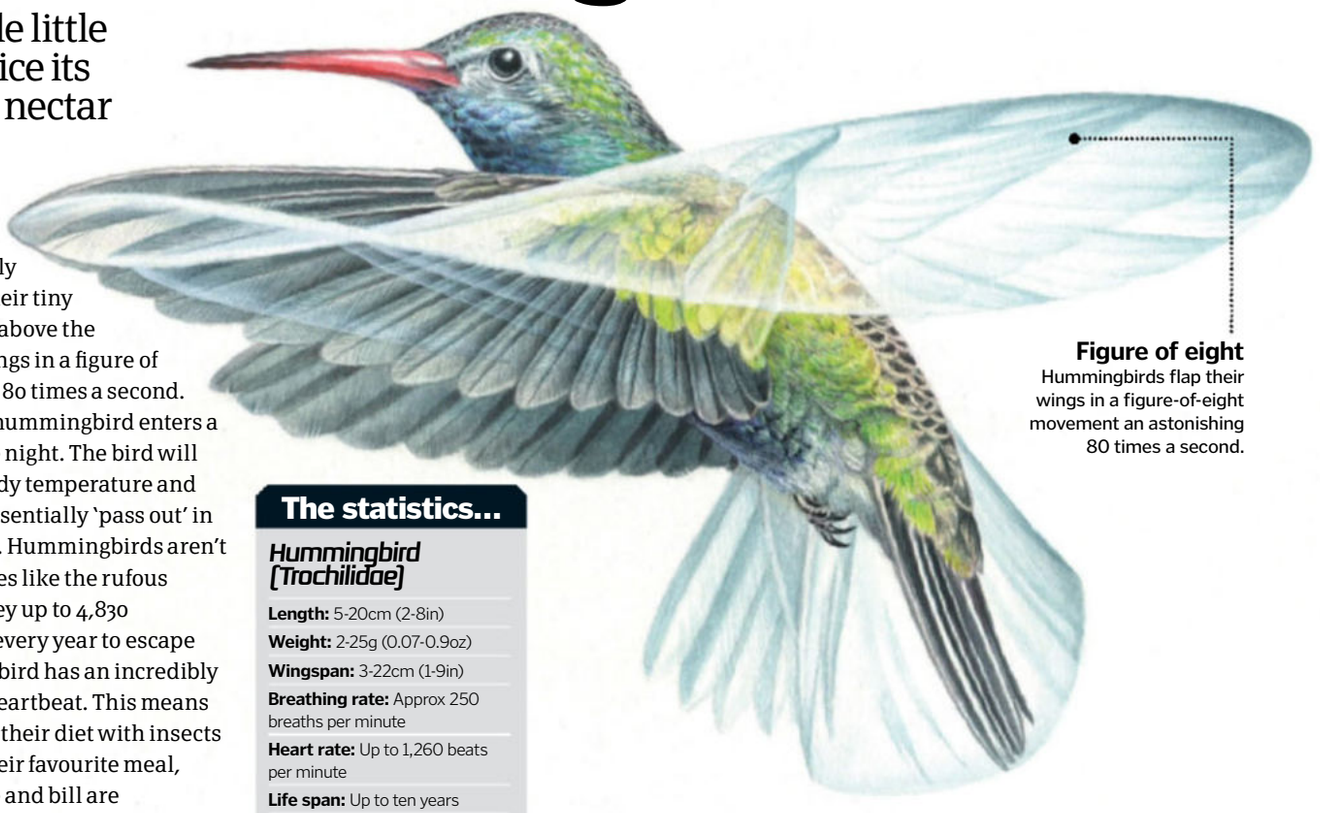


**Figure of eight**
Hummingbirds flap their wings in a figure-of-eight movement an astonishing 80 times a second.

Incredibly, hummingbirds find it immensely difficult to walk due to their tiny legs. Instead, they hover above the ground flapping their wings in a figure of eight movement, around 80 times a second. All this work means the hummingbird enters a state of torpor during the night. The bird will significantly lower its body temperature and metabolic activity and essentially 'pass out' in order to conserve energy. Hummingbirds aren't lazy, though; some species like the rufous hummingbird can journey up to 4,830 kilometres (3,000 miles) every year to escape the cold winter. The tiny bird has an incredibly fast breathing rate and heartbeat. This means they have to supplement their diet with insects and tree sap. Nectar is their favourite meal, though, and their tongue and bill are specifically shaped to devour it.

### The statistics...

***Hummingbird (Trochilidae)***

**Length:** 5-20cm (2-8in)
**Weight:** 2-25g (0.07-0.9oz)
**Wingspan:** 3-22cm (1-9in)
**Breathing rate:** Approx 250 breaths per minute
**Heart rate:** Up to 1,260 beats per minute
**Life span:** Up to ten years

# The biggest jellyfish on record

## Watch out for the 37-metre stinging tentacles

The lion's mane jellyfish, or Cyanea capillata, is the biggest member of the jellyfish family by a considerable margin. Its tentacles can extend more than 30 metres (98 feet), with the largest on record reaching a whopping 37 metres (120 feet) in length. This makes it one of the longest animals in the world! These tentacles also give the jellyfish its name, thanks to their red and yellow colour.

Their traditional habitat is in the cold waters of the Arctic, Northern Atlantic and Northern Pacific Oceans, but in recent years they have been spotted in more southerly waters, and even around British coastlines.

All jellyfish are renowned for their sting, and the lion's mane's is pretty potent. Caused by capsules on the tentacles called nematocysts or cnidocytes, contact with the lion's mane will cause painful burns and blisters and they can even be fatal if a human or animal becomes entangled and exposed to repeated stings.

The lion's mane traditionally feeds on plankton and small fish, but is common prey for sea turtles, birds and even other jellyfish

## KEY DATES
### DEVELOPMENT OF THE LITHOSPHERE

**3.8bya**
The lithosphere begins to break up, forming tectonic plates, allowing volcanoes and mountains to form.

**1914**
Joseph Barrell is the first to present the theory that the Earth's crust is made up of two layers.

**1912**
Alfred Wegener proposes the theory of continental drift, but his findings are met with disdain by many scientists.

**1940**
Dr Reginald Daly realises the asthenosphere has to be nearly liquid to explain its reaction to melting ice caps.

**1960s**
Scientists finally agree that movement under the sea is caused by tectonic plates shifting.

**DID YOU KNOW?** *Movement along the San Andreas fault line is pushing Los Angeles 4.6cm (1.8in) closer to San Francisco every year*

# The lithosphere

## A closer look at the land on which we stand

The Earth is made up of four main layers: the inner core, outer core, mantle and the crust. The lithosphere includes the crust and the top portion of the mantle. It can be as thick as 100 kilometres (62 miles) and covers the entire planet, either as land or as ocean.

The lithosphere is constantly moving, but very slowly. It is broken up into huge sections known as tectonic plates. When two plates collide, the impact creates huge shock waves that cause earthquakes and tsunamis on the surface. They move around because material from the lower mantle rises and sinks in swirling convection currents, dragging the plates along with them.

The lithosphere can be broken down into two main layers. The deepest layer of the lithosphere is the solid upper mantle which floats on the softer mantle called the asthenosphere below. The upper layer, effectively Earth's surface, is known as the pedosphere and reacts with the atmosphere above.

The lithosphere's strength is crucial to life existing on Earth as it protects us from the incredible heat of the Earth's core, while providing a stable landmass for us to live on.

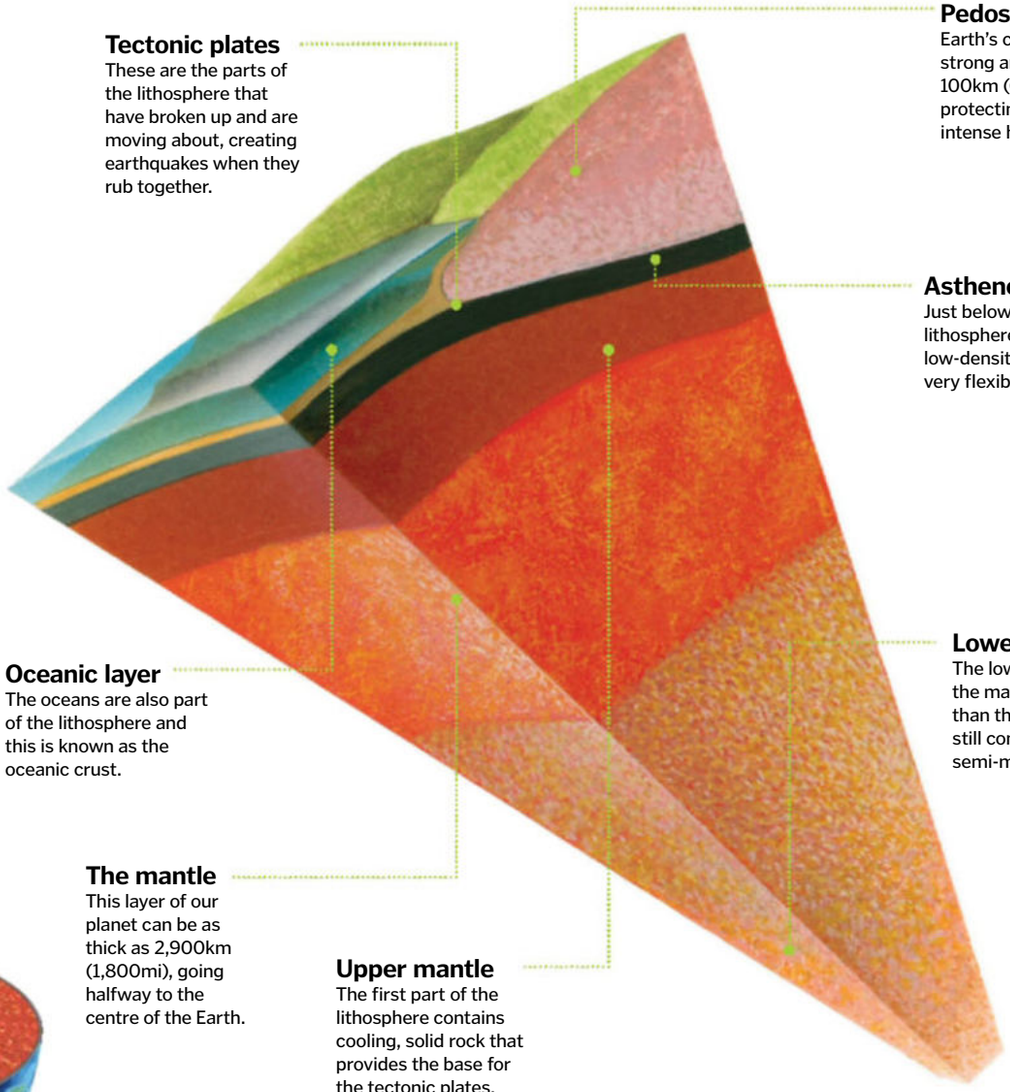
## How did continents form?

The lithosphere has been around since the formation of the Earth, but it has been hypothesised that all land was once joined together. This supercontinent is called Pangaea, Greek for 'all lands.' The theory goes that as the tectonic plates split apart, they pulled the various landmasses with them, forming the continents we know today.

If you look closely, South America and Africa fit together well, with North America slotting neatly into the middle. Further evidence for Pangaea comes in the form of fossils found in both Africa and South America. The animals that formed the fossils are unlikely to have lived in both continents unless they were once conjoined.


## Cutting through the Earth

**What would the Earth would look like if you sliced a 100km (62mi) section out of it?**



**Tectonic plates**
These are the parts of the lithosphere that have broken up and are moving about, creating earthquakes when they rub together.

**Pedosphere**
Earth's crust is strong and up to 100km (62mi) thick, protecting us from intense heat.

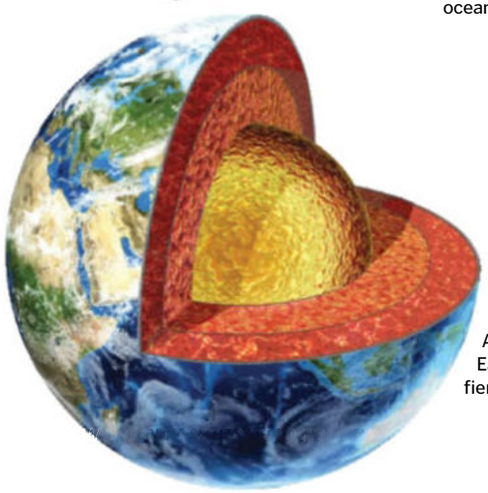
**Asthenosphere**
Just below the lithosphere, this low-density layer is very flexible.

**Oceanic layer**
The oceans are also part of the lithosphere and this is known as the oceanic crust.

**Lower mantle**
The lower half of the mantle is cooler than the core, but still contains semi-molten rock.

**The mantle**
This layer of our planet can be as thick as 2,900km (1,800mi), going halfway to the centre of the Earth.

**Upper mantle**
The first part of the lithosphere contains cooling, solid rock that provides the base for the tectonic plates.



A cross-section of the Earth, showing its fiery-hot inner layers

"The electrons from the cloud power toward the ground, discharged as a bolt of lightning"

# Supercell thunderstorms

## Why do those blinding flashes and ominous rumbles occur?

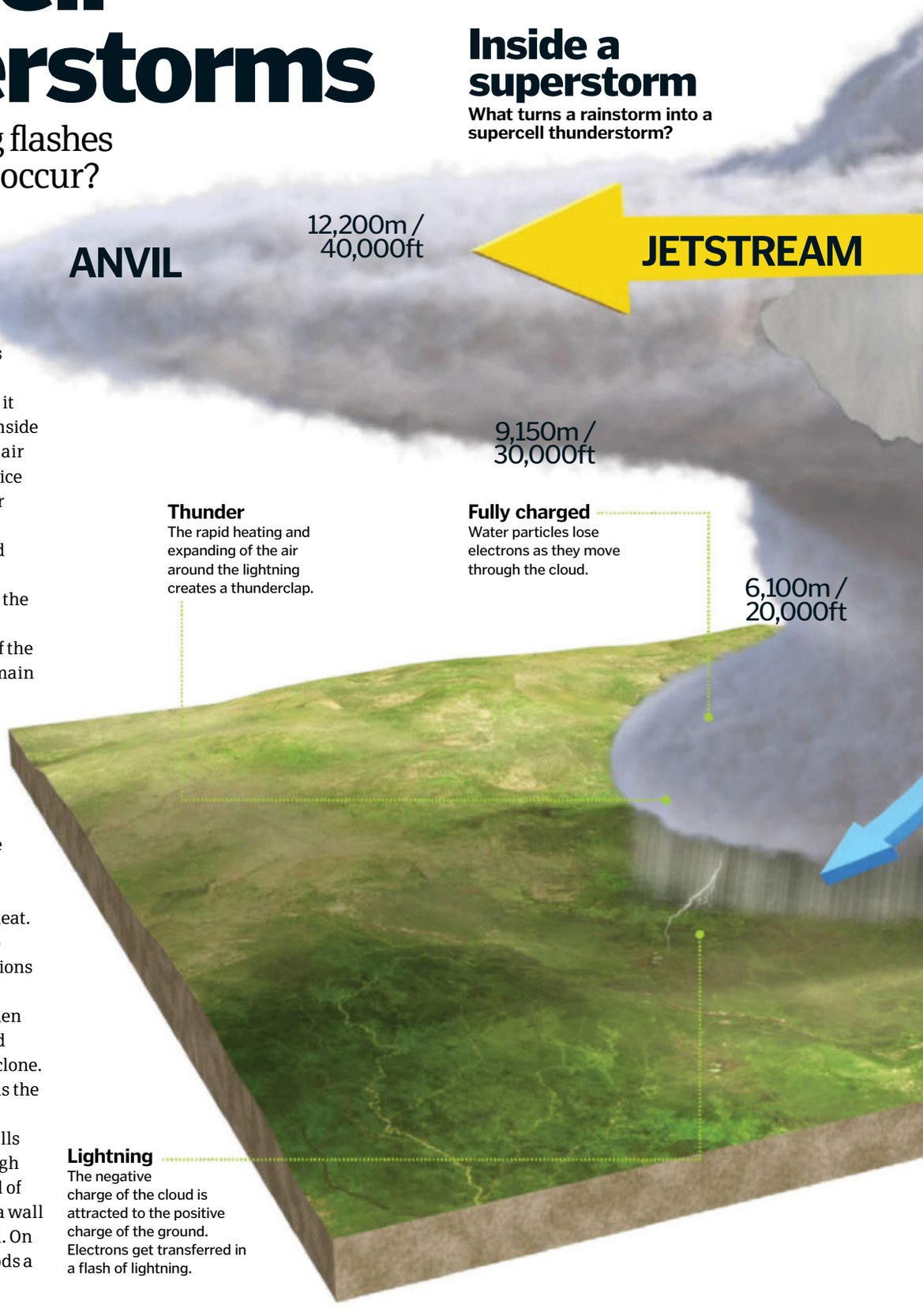
Thunderstorms are both spectacular and a bit scary, but what creates this awe-inspiring mix of rain, thunder and lightning? On warm days, hot air forms near the Earth's surface. As hot air is less dense than cold air, it rises, pushing through the colder air above it. Eventually it cools enough for the moisture contained inside the air to condense. As the moisture in the air turns to liquid, it forms ice crystals. These ice crystals are dense, so they become heavier than the updraft and begin to fall down through the cloud. As they descend toward Earth they thaw and become rain.

When the water particles move through the cloud, electrons are stripped from them. Positively charged particles sit at the top of the cloud and negatively charged particles remain at the bottom. This induces a positive charge on the Earth's surface below, so the clouds are desperate to hand over their spare electrons. Once the charge has built up, the electrons from the cloud power toward the ground, discharged as a spark of electricity that we see as a bolt of lightning. As lightning can travel at a breakneck 160,000 kilometres (100,000 miles) per hour, it creates a lot of heat. This causes the air around the lightning to expand extremely quickly, creating vibrations that we hear as thunder.

Supercell thunderstorms are formed when thunderstorms and high winds collide and combine, causing what is called a mesocyclone. This will often lead to a tornado forming, as the rapidly rotating wind combines with the updraft to create a weather system that pulls objects upward with tremendous force. High precipitation supercells are the worst kind of them all, as the tornado is hidden behind a wall of water, making it tricky to spot and avoid. On top of it all, the heavy rain makes flash floods a real risk.

## Inside a superstorm

**What turns a rainstorm into a supercell thunderstorm?**



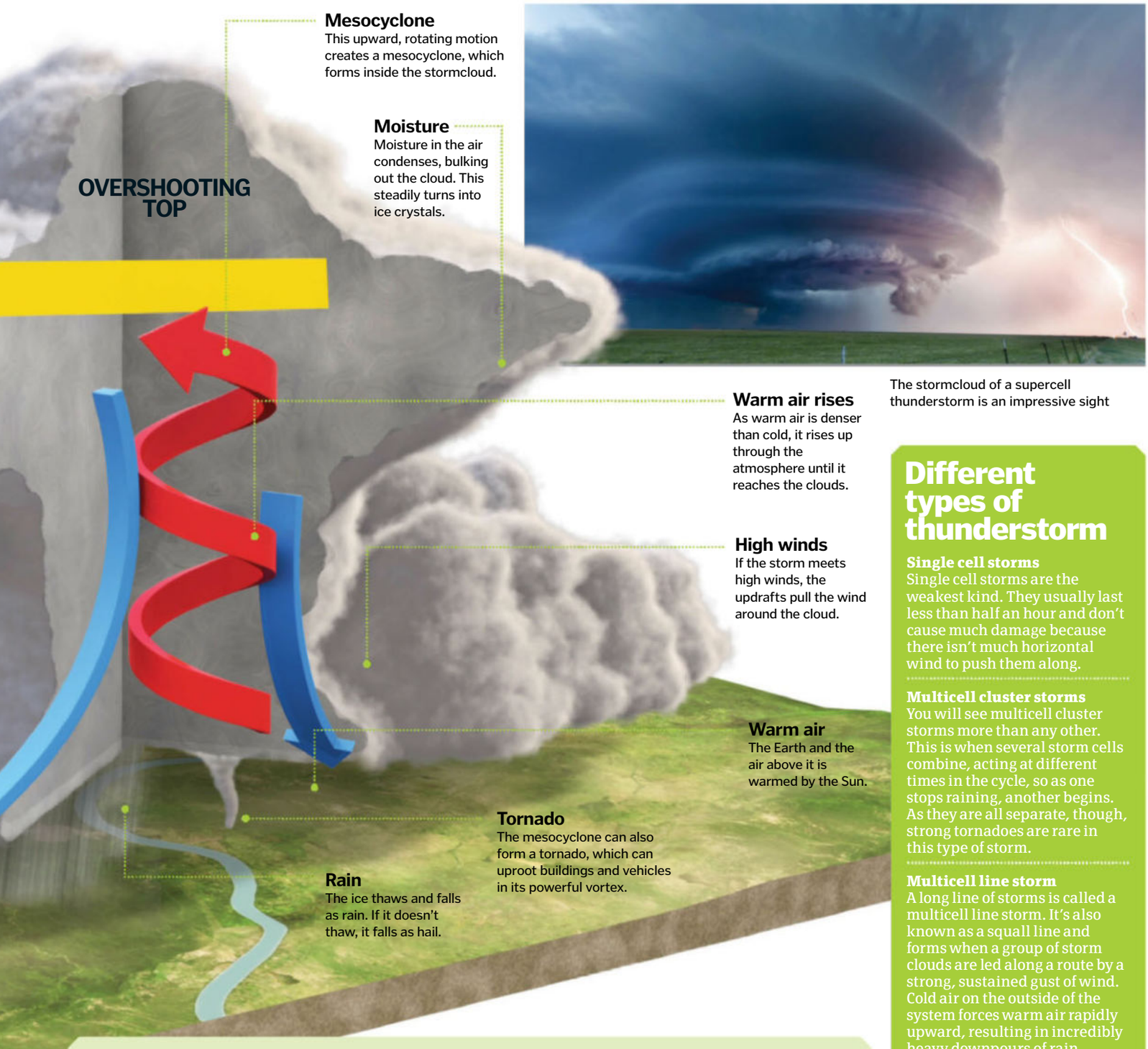
# AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

**See the formation of an incredible mesocyclone**

www.howitworksdaily.com

**DID YOU KNOW?** *Supercell tornadoes can bring hail more than 1.9cm (0.75in) in diameter*




**Mesocyclone**
This upward, rotating motion creates a mesocyclone, which forms inside the stormcloud.

**Moisture**
Moisture in the air condenses, bulking out the cloud. This steadily turns into ice crystals.

**Warm air rises**
As warm air is denser than cold, it rises up through the atmosphere until it reaches the clouds.

**High winds**
If the storm meets high winds, the updrafts pull the wind around the cloud.

**Warm air**
The Earth and the air above it is warmed by the Sun.

**Tornado**
The mesocyclone can also form a tornado, which can uproot buildings and vehicles in its powerful vortex.

**Rain**
The ice thaws and falls as rain. If it doesn't thaw, it falls as hail.



The stormcloud of a supercell thunderstorm is an impressive sight

## Different types of thunderstorm

**Single cell storms**
Single cell storms are the weakest kind. They usually last less than half an hour and don't cause much damage because there isn't much horizontal wind to push them along.

**Multicell cluster storms**
You will see multicell cluster storms more than any other. This is when several storm cells combine, acting at different times in the cycle, so as one stops raining, another begins. As they are all separate, though, strong tornadoes are rare in this type of storm.

**Multicell line storm**
A long line of storms is called a multicell line storm. It's also known as a squall line and forms when a group of storm clouds are led along a route by a strong, sustained gust of wind. Cold air on the outside of the system forces warm air rapidly upward, resulting in incredibly heavy downpours of rain.

## Thunderbolt facts

**Hot!**
The air around lightning heats to a scorching 27,760°C (50,000°F). This is five times hotter than the surface of the Sun.

**Powerful!**
The five billion joules of energy in a single lightning bolt could fulfil a home's electricity needs for a whole year.

**Loud!**
Thunder can be as loud as 120dB. This is loud enough to be heard over the crashing guitars of a rock concert.

**Fast!**
Tornadoes can move at over 113km/h (70mph), which is as fast as the highest current speed limit on British motorways.

"The alkali in the water and iron from the lava react and solidify into a gel-like substance"


# Aurora borealis

## The jaw-dropping lights that brighten the night sky explained

The pattern inside a piece of agate is unique to every single specimen

# Agate

## How do these amazing, banded gemstones form?

Agate is a mineral, prized around the world for its bold colours and dynamic, swirling patterns. It's made from silicon dioxide and is classified as chalcedony, which is a microcrystalline form of quartz.

They are created after gas bubbles form inside flowing lava. Small amounts of silica and alkali-bearing water seep into these bubbles as they form as well as after. The alkali in the water and iron from the lava react and solidify into a gel-like substance, making a band of iron hydroxide inside the bubble. As the water either escapes or evaporates, the iron hydroxide remains and crystallises, causing that distinctive band of colour.

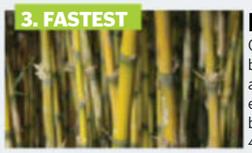
Lava and rock continue to form around the newly formed stone until it has built up into the elaborate natural product we see today. Due to the unique way agate is created, no two pieces are ever exactly the same.

1. FAST

**Sequoia**
Sequoia trees can grow up to an impressive 60cm (24in) in a year, but astonishingly enough, they grow faster as they get older.

2. FASTER

**Kelp**
Using photosynthesis and nutrient-rich water to grow very rapidly, kelp reaches 45cm (18in) closer to the surface of the water each day.



3. FASTEST

**Bamboo**
Certain species of bamboo grow at an astonishing 91cm (35in) every day. The tallest bamboo in the world is 40m (130ft) tall.

**DID YOU KNOW?** *The oldest creosote bush in the world has been carbon dated to 11,700 years ago*

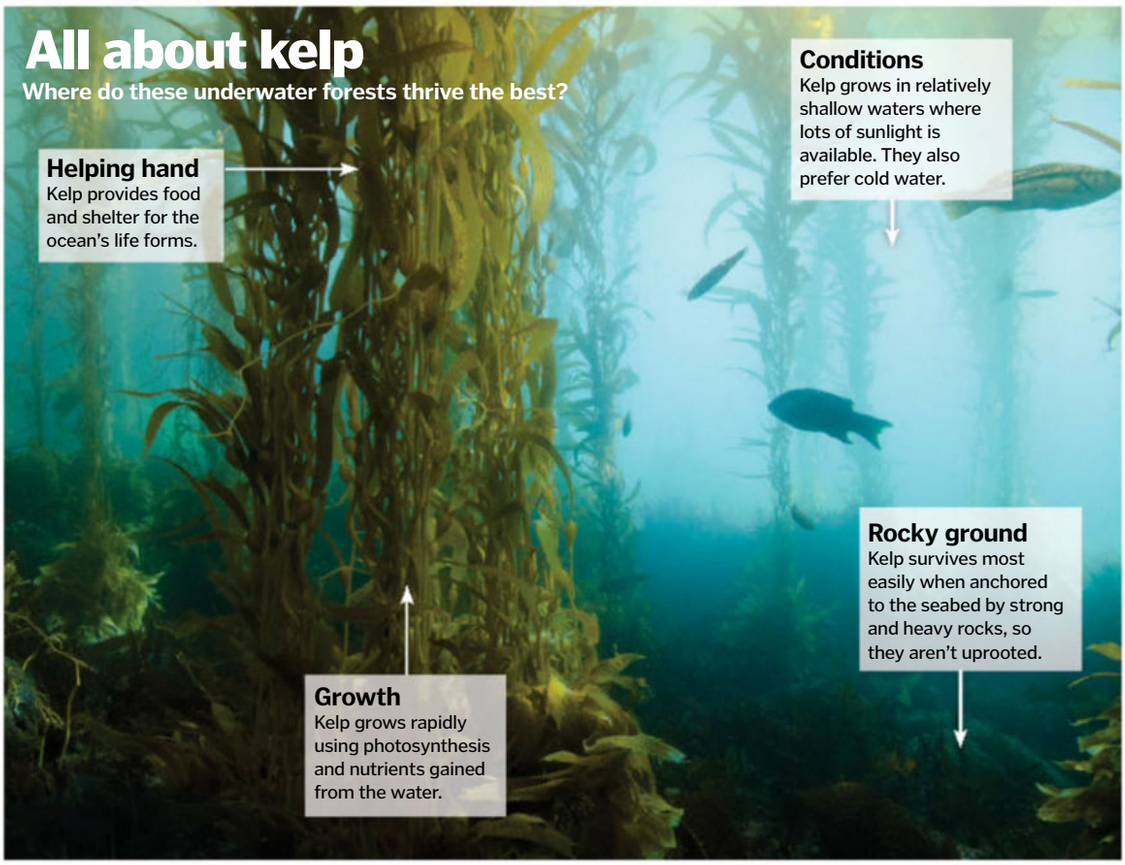
# Kelp forests

## The wonder of these underwater canopies revealed

We may think forests only grow on land, but looming over the ocean floor is a giant canopy of kelp. This species of brown algae can be found along the west coast if North America and can grow up to 46 centimetres (18 inches) in one day.

Just like plants on land do, kelp uses energy from the Sun to make its own food through photosynthesis. This dependency on light is why they form in shallow waters, very rarely deeper than 40 metres (130 feet). Also, they only grow in cold water, preferring temperatures of between five and 20 degrees Celsius (41 to 68 degrees Fahrenheit). The colder the water is, the more nutritious nitrogen is available to them.

Kelp forests are a vital part of the ocean's ecosystem and mammals like seals and gulls couldn't flourish without it. The canopies of algae provide essential nutrients, as well as being an excellent hiding place from predators.




Creosote bush is known as 'greasewood' as a plant and 'chaparral' as a medicinal herb

# Creosote bush: survival secrets

## How this unassuming shrub can live for thousands of years

The plant Larrea tridentata doesn't look that spectacular at first sight, but peer closer and you'll find that these plants are among the oldest living organisms on Earth. The oldest creosote bush colony is known as King Clone and it's estimated to be 11,700 years old. Found in the Mojave Desert in California, the secret to its survival lies in its waxy leaves. The leaves are coated with a resin that stops water evaporating in the scorching sun. This means it can retain its leaves all year round, photosynthesising throughout the summer when most other plants have had to drop their leaves or let them wither. The leaves are also smelly, which deters animals from eating it. However, Native Americans braved the not-too-attractive smell to use the leaves as an antiseptic, brewing it in tea to cure colds and flus.

# The Pantheon

## Bask in the brilliance of Roman architecture

You may have heard of the Roman Emperor Hadrian – he has a wall named after him in Northern England – but his most famous and influential project is the Pantheon. Nestled in the heart of Ancient Rome, it is the largest unreinforced concrete dome in the world. It was completed in around 125 CE after the original was burnt to a cinder. The Pantheon served as both a temple to the gods and also as a place where the emperor could make public appearances.

The front of the structure is Greek in style and is not too different from many of the buildings in Ancient Athens in its pomp. The remainder is a classical Roman style and contains an 8.8-metre (29-foot) oculus in the dome. This opening allowed the Sun to light the main chamber. While the Greek columns were made of marble, the Roman arches inside are constructed from brick. The vast dome is held up by internal arches and step rings and signifies a major breakthrough in architecture. These techniques enabled the Romans to construct the biggest structures ever seen in that period.

With the fall of the Western Roman Empire, Europe experienced a period of architectural decline known as the Dark Ages. As cities across the empire were ransacked, many of the great Roman buildings were destroyed by barbarian hordes. One of the exceptions to this was the Pantheon. It was converted to a Christian Church called the St Mary of the Martyrs in 608 CE. Christianity was the main religion of Europe at the time so this is probably what saved it from being levelled. Currently, the building serves as a symbolic tomb for the old Italian monarchy and as a constant reminder of the greatness of Ancient Rome.




**Facade**
The writing on the front façade reads: "M Agrippa LF. Cos Tertium Fecit" ("Marcus Agrippa, son of Lucius, three-time consul, made this").

**Columns**
Originally covered in white marble, the porch's eight 11.8m (39ft) Corinthian columns were copied by the Romans from Ancient Greek structures such as the Parthenon.

**Exterior**
The bronze doors of the Pantheon weigh 20 tons and the exterior walls are 7.5m (25ft) thick.

## Pretenders to the crown

From the Panthéon in Paris to the Pantheon of National Revival Heroes in Bulgaria, the legendary structure has influenced building style around the world. You'll notice the symmetrical design with rows of Corinthian columns reproduced in the US Capitol Building and the Jefferson Memorial in Washington, USA, and a little closer to home in the Villa Almerico-Capra in Italy. Ancient Roman architecture has been the template for many structures and since the Pantheon is undoubtedly one of the best preserved of them all, it's only natural to look to it for inspiration. As they say, imitation is the sincerest form of flattery.

# HEAD 2 HEAD
## BIGGEST DOMES IN THE WORLD

**1. BIG**

### Oita Bank Dome
This impressive stadium in Japan played host to three fixtures in the 2002 FIFA World Cup and has a dome of 270m (886ft).

**2. BIGGER**

### AT&T Stadium
The 80,000-capacity home of the NFL's famous Dallas Cowboys, the dome is the biggest in the United States at a huge 274m (900ft).

**3. BIGGEST**

### Singapore National Stadium
At an immense 312m (1,024ft), the retractable roof is the daddy of all domes.

**DID YOU KNOW?** *Every year, on 21 June, the rays of the Sun at the summer equinox shine from the oculus through the front door*

### Oculus
The small hole in the top of the dome was originally the only light source within the building.

### Dome
The dome's rotunda is 43.3m (142ft) in diameter and is constructed from pozzolanic concrete.

### Main room
The main room is designed to symbolise the heavens while the oculus depicts the Sun.

### Drainage system
Rain water entering through the oculus is carried from the centre of the temple through drains.

### Roman religion
Seven shrines represent the five planets the Romans knew of (Mercury, Venus, Mars, Jupiter and Saturn) and the Sun and Moon.

### Interior design
Due to renovation and restoration projects over the years, the interior is now decorated in a Christian design rather than Roman.

## Pantheon through the ages

**126 CE**
A temple to all the Roman gods

**1600**
A Renaissance period regeneration

**1835**
The short-lived bell towers are seen here

**2014**
Today, it hosts mass and weddings

"The rock immediately above and below the fossil is tested, so an estimate can be made of the dinosaur's age"

# How to tell a dinosaur's age

## Digging up the science behind dating fossils

One of the most important fossils ever found, Archaeopteryx bridges the evolutionary gap between dinosaurs and birds

Telling the age of dinosaur bones is a tricky business. A technique called radiometric dating is frequently used, which works by finding the age of the rocks surrounding the fossil. The number of neutrons in the nuclei of the rock's isotopes is measured. If there are more unstable radioactive neutrons than stable, the element is younger as it has not had as much time to shed particles and become stable. Essentially, the remaining amount of unstable isotopes tells you the age. The ideal forms of isotope to find and use are uranium-238 and uranium-235, as these have a longer radioactive half-life so can date the very oldest fossils. The rock immediately above and below the fossil is tested, so an estimate can be made of the dinosaur's age. Experts describe the process as a sort of 'natural clock'. Alternatively, a process known as palaeomagnetic stratigraphy is used. The Earth's magnetic field has reversed pole numerous times so judging the magnetic properties of iron oxides can narrow down findings. They essentially act as little compasses. Current techniques can only narrow the age down to an estimate within 10,000 years but with millions of years of history to play with, this is still very impressive. A discovery in 2005 rocked the world of palaeontology when soft tissue was reportedly found hidden within a T-rex fossil. It was previously believed that the Mesozoic era was too long ago for soft tissues to last. However, iron within the body preserved the tissue formaldehyde, by cross-linking amino acids to make it more resistant to decay.

'Sue' is one of the best-preserved Tyrannosaur rex skeletons ever discovered

### What's the difference between a palaeontologist and an archaeologist?

#### Sounds like an old joke, but there's a vital distinction

There is often confusion between these two studies as they are closely related and often overlap with each other. Palaeontology is primarily focused on plant and animal fossils while archaeology is based more on humans and human culture of yesteryear. Contrary to popular belief, archaeologists have nothing to do with fossils. Therefore it can be said that palaeontology is geology based while archaeology is more about anthropology.

A fossil like this would be of great interest to a palaeontologist but not so much to an archaeologist

**Learn more**

For more on fossils, check out *A History Of Life In 100 Fossils*, a book from Paul Taylor and Aaron O'Dea that describes how important fossils are to see how life on Earth evolved.

"A discovery in 2005 rocked the world of palaeontology when soft tissue was reportedly found hidden within a T-rex fossil"

## KEY DATES
### HEARING AID HISTORY

**Early-1800s**
Simple hearing trumpets are first used to amplify sound and help people who are hard of hearing.

**1898**
The first commercial hearing aid is priced at $400, making it only affordable to the upper classes.

**1952**
The invention of the transistor allows hearing aids to downsize but still use the same technology.

**1990s**
Digital and fully automatic devices with different channels are available for various hearing issues.

**2014**
Hearing aids are now miniscule and can fit snugly into the ear, becoming almost invisible but no less effective.

**DID YOU KNOW?** *Modern smartphones have an app that can be downloaded and used as a fully operational hearing aid*

# Flint weapons

## How human tool and weapon manufacturing first began

A selection of Stone Age flint weapons including arrowheads and spearheads

Before metals were first extracted during the Bronze Age, tools and weapons were made out of stone. A fundamental material used in the Stone Age was a sedimentary rock known as flint. Strong and with sharp edges, flint is plentiful in chalk and limestone beds around the world, which made it ideal for the first primitive tools and weapons. The stone was first mined over a million years ago during the Paleolithic period, using an extraction method known as flintknapping. This would involve chipping away at the seam of rock until the desired shape of blade was created. Some of the earliest flint tools were hand axes, which were used to hunt animals, chop wood, dig and even start a fire. Early weapons were big and blunt while later arms were better crafted, polished and sharper. From these primitive beginnings would arise the first daggers, spears and arrowheads, becoming an integral part in Stone Age warfare, toolworking and hunting.

### The age of stone

**The eras in which flint was a major component**

**Paleolithic period**
**Approx 2.5 million years ago**
Flint tools of this age were at their most primitive with only basic tools like hand axes made. This type of toolwork was used by Homo erectus as well as Homo sapiens.

**Mesolithic period**
**Approx 15,000 years ago**
Tools became more sophisticated in this era, being used in carpentry to make the first structures. The first pottery was made in this period, in no small part due to this evolution.

**Neolithic period**
**Approx 12,000 years ago**
Emerging agriculture was the influence on the tools of this age with scythes made to harvest grain. Tools of this era also had a distinctive appearance due to increased polishing.

# The first hearing aids

## From 19th-century ear trumpets to microchips

Although they may look like something out of a cartoon, ear trumpets were used frequently throughout the early-19th century. The first type of hearing aid had a large surface area that amplified sound that was directed toward the ear. They were made of metal, silver, wood or animal horns and were incredibly bulky. However, as their use became more widespread, they featured a collapsible design so the ear trumpet could be carried in pockets and removed when necessary. Horns were so popular that even midwives would use a similar instrument to the ear trumpet for listening to pregnant ladies' wombs.

Early hearing aids could hardly be described as 'inconspicuous'

"The occupation could range from a short hair trim all the way through to complex operations"

# Horse shoeing

## Why do horses wear shoes and how are they fitted?

Ever since horses were first domesticated thousands of years ago, horsemen realised the importance of protecting their animals' feet. On hard or rocky terrain, shoes protected a horse's hooves from cracking or wearing down faster than they could grow. In soft, wet terrain – like the farmlands of northern Europe – shoes stopped their hooves from becoming porous and unstable, as well as helping the horse gain a good footing.

To prepare the foot, a farrier – an expert who shoes horses for a living – gives the horse a basic manicure by levelling off the hoof with a rasp and trimming excess growth. Next, they take a shoe made steel or aluminium and heat it in a forge until it glows red-hot. The shoe is quickly placed against the hoof to makes an impression, which the farrier uses as a guide for reshaping the malleable metal with a hammer and anvil. The shoe is cooled in water and fixed to the hoof with nails, which are angled so they exit the outer wall of the hoof and can be bent down to form clenches. Finally, the edges are smoothed down with a rasp.

### How are horse shoes removed?

Just like our fingernails, horse's hooves are constantly growing, which means their shoes need to be removed and re-fitted regularly. To remove a shoe, the clenches in the hoof wall are straightened out with a buffer and hammer, before the whole shoe is levered off with pincers.

If all this talk of burns, nails, and pincers has you wincing – don't! Just like our fingernails, hooves don't have nerve endings. So long as the nails are placed correctly, without touching fleshier parts of the foot, the horse feels nothing at all.

A farrier (a specialist in horse hoof care) using pliers to remove an old shoe from a horse's hoof

# Barber surgeons

## The role of a medieval practitioner

If you asked for a short back and sides in the Middle Ages, you may get more than you bargained for. This was due to the birth of the 'barber surgeon' where barbers doubled up as doctors and dentists. The occupation could range from a short hair trim all the way through to complex operations. In this age, physicians were strictly employed in an academic role so barber surgeons were essentially the infantry of the doctoring profession, looking after soldiers in battlefield hospitals and serving the public.

This system had pros and cons. On the plus side, the barbers learnt many new medical techniques through trial and error, and even improvisation. It was in this age that wine was first used as an antiseptic and opium as a crude form of anaesthetic. However, the lack of barber surgeon training meant that incorrect forms of treatment such as bloodletting and trepanning still existed. The role of a barber surgeon effectively ended in 1745 when a bill was passed to separate the two roles. Haircuts were now given without the patient fearing an unexpected amputation.

The famous barber's pole originates from the age of the barber surgeon with the red illustrating blood and white showing the bandages

## HEAD 2 HEAD
MOST EXPENSIVE CROWNS

**1. PRICEY**

### Imperial Crown of Austria
The eight squares of diamonds, pearls and detailed enamel work makes the crown of Austria worth a cool £10mn ($16.5mn).

**2. PRICIER**

### Bavarian Crown
The centrepiece of the Bavarian Crown was the Wittelsbach Diamond. This makes the headpiece, made in 1804 for Maximilian I, worth around £10.5mn ($17.5mn).

**3. PRICIEST**

### St Edward's Crown
The crown of Britain is estimated to be worth a staggering £24mn ($39mn), which is more than the most expensive car ever.

**DID YOU KNOW?** *The Sovereign's Sceptre is topped with the First Star of Africa, the biggest flawless cut diamond in the world*

# The Crown Jewels

## How the British monarchy built up the most famous jewellery collection in the world

Along with Buckingham Palace, one of the most famous things about the British monarchy is the incredible collection of crowns, orbs, sceptres and precious stones that makes up what's collectively called the Crown Jewels.

Stored in the Jewel House of the Tower of London since the beginning of the 14th century, the collection has been a symbol of the monarchy ever since the coronation of Edward the Confessor in 1042. It was for this reason that many valuable pieces were lost as Lord Protector Oliver Cromwell ordered the Crown Jewels to be melted. As they represented the monarchy's wealth and power, gold items were melted down and jewels sold. The only items that remained were the Anointing Spoon and three ceremonial swords – the Swords of Temporal Justice, Spiritual Justice and Mercy.

The collection was rebuilt in 1660 after Charles II regained the throne. He commissioned replicas of the destroyed pieces at a cost of £13,000, which today would be around £1.7 million ($2.8 million).

The Crown Jewels do have a practical purpose, though, as they form the regalia that accompanies every coronation ceremony. The crown that was used for Queen Elizabeth II's coronation is St Edward's Crown. The jewel-encrusted golden headpiece weighs a hefty 2.23 kilograms (4.92 pounds), or about the same as a medium-sized rabbit.

Queen Elizabeth II wearing St Edward's Crown at her coronation

## The crowning glory

**The story behind each Crown Jewel**


### 1. St Edward's Crown
This gold crown is inlaid with sapphires, topazes, citrines, tourmalines and amethysts. It is the crown used at the monarch's coronation.

### 2. Imperial State Crown
Every time the monarch opens Parliament, this crown is the one they wear. It contains an incredible 3,000 gems including the Second Star of Africa.

### 3. The Sovereign's Sceptre
Topped with the 530.2-carat Star of Africa, the Sovereign's Sceptre is handed to the new monarch at their coronation. It represents the sovereign's good governance and temporal power.

### 4. The Sovereign's Orb
The other item handed to the monarch during their coronation. A hollow gold sphere featuring sapphires, rubies and emeralds, while the cross on top of it is inlaid with diamonds. It represents power and Christianity.

### 5. The Ampulla
During the coronation ceremony, the head of this golden eagle is unscrewed as it contains the oil used to anoint the incoming monarch.

### 6. Coronation Spoon
The oldest surviving piece of the collection. Oil is poured from the Ampulla onto the Anointing Spoon, where it is placed on the monarch's forehead by the Archbishop of Canterbury.

### 7. The Armills
These gold and enamel bracelets are lined with velvet and worn by the monarch, and are thought to represent wisdom.

### 8. Spurs
No longer worn by the monarch, the spurs are made from gold, velvet and gold thread and were first used for the coronation of Richard the Lionheart.

### 9. Altar Set
Part of Charles II's extravagant rebuilding included a full altar set, including a golden chalice and a plate used for communion.

# BRAIN DUMP

Because enquiring minds need to know...

## Want answers?

Send your questions to...

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howitworks@imagine-publishing.co.uk

## MEET THE EXPERTS

### Who's answering your questions this month?

**Luis Villazon**

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He has been writing about science and technology since before the web was invented. His sci-fi novel *A Jar of Wasps* is out now.

**Sarah Bankes**

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

**Alexandra Cheung**

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

**Laura Mears**

Laura studied biomedical science at King's College London and has a masters from the University of Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

**Shanna Freeman**

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

The Sun will expand to consume Earth before Earth will be dragged into it

# How much closer would we have to be to the Sun to be pulled into it?

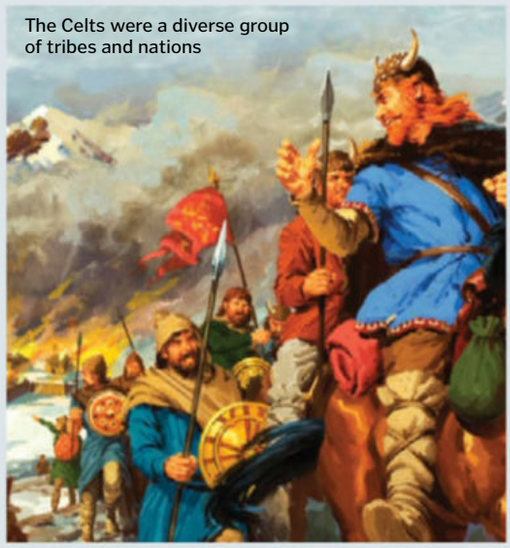
**Mel Litchfield**

■ If depends on what you mean by "we." The Earth, for example, will never be pulled into the Sun by its gravity. It's estimated that in about five billion years, the Sun will go into a red giant phase and is more likely to expand out to meet the Earth (and evaporate it). But an object – discounting elements like a spacecraft's own momentum – travelling from the Earth toward the Sun would have to approach to about 250,000 kilometres (155,300 miles) to be taken in by the Sun's gravity. That's less than the distance between the Earth and the Moon. If you were in a spacecraft, you'd have to worry about things like radiation and the intense heat before you were concerned about being sucked into the Sun. **SF**

# Were the Celts Irish, Scottish, or Welsh?

**Cameron Alworth**

The history of the Celts is a subject of hot debate among historians, geneticists and archaeologists, but it is generally agreed that the first true Celtic people, known as the Hallstatt culture, lived in Austria between 800 and 450 BCE. The Celts were not a single group of people, but a number of tribes who shared similar language and culture. They were among the first people in the world to use iron tools and they quickly fanned out across Europe, including Britain and Ireland. After the Roman invasion of Europe, most of the Celtic culture was lost, so today Ireland, Scotland and Wales are some of the last remaining places where Celtic languages are still spoken. **LM**



The Celts were a diverse group of tribes and nations

# How are diamonds cut?

**Edward McAllister**

Diamond is the hardest substance known in nature, so cutting it is far from easy. To saw a diamond in half you can use a phosphor-bronze circular saw blade rotating at 15,000rpm, or a laser. If the cut is in line with the 'grain' of the diamond's crystal lattice, you can saw a shallow groove and then cleave it neatly in two with a thin steel blade that you strike with a hammer. Once diamonds have their rough shape, they are rounded by mounting them in pairs in a kind of lathe so that they spin in opposite directions. Each diamond grinds away at its partner until they are perfectly smooth. The facets that give the diamond its sparkle are polished into shape using grinding discs coated with diamond dust. Turning a rough diamond into a brilliant cut gemstone with 58 facets involves grinding away about half of the original diamond. **LV**

# FASCINATING FACTS

## Sunscreen factors in radiation

SPF (Sun Protection Factor) is a measure of how much UVB radiation that sunscreens block. For example, SPF15 allows 1/15th (seven per cent) of UVB rays through, while SPF50 only permits 1/50th (two per cent).

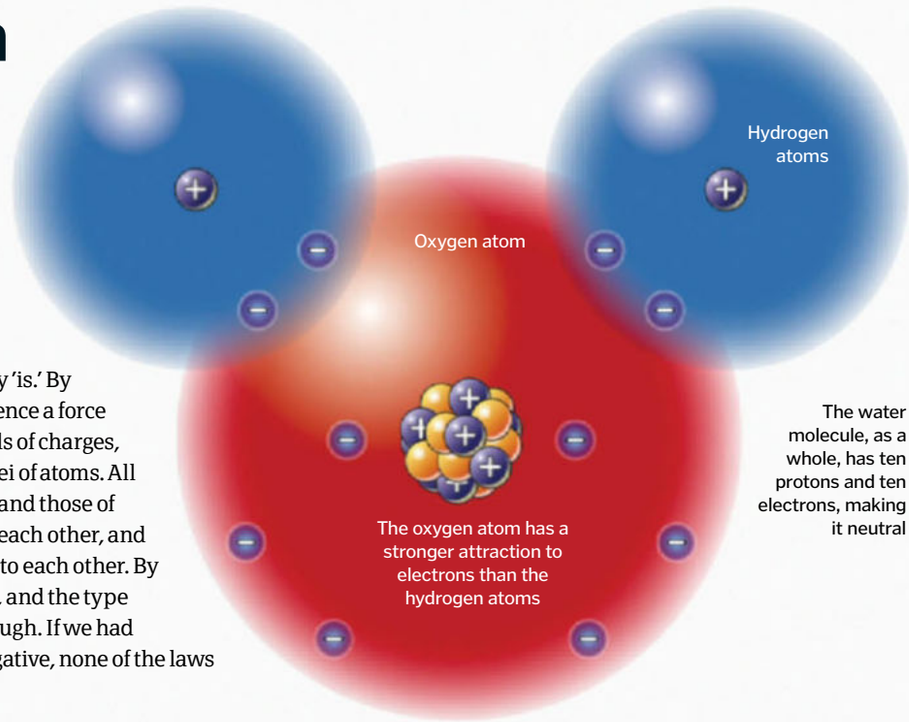
## Electrical devices can keep track of the time even when they're turned off

Computers have a small rechargeable battery that powers the internal clock. Mobile phones will get the correct time from the phone network as soon as they switch back on.

# What does it mean when you say an electron has a negative charge?

**Rory Weston**

Electrical charge is a fundamental property of the particles that make up matter, but it's difficult to pin down what it really 'is.' By definition, charge is what causes a particle or object to experience a force when exposed to an electromagnetic field. There are two kinds of charges, the kind carried by electrons and the kind carried by the nuclei of atoms. All that matters is that charges of the same kind repel each other and those of different or opposite kinds attract each other. Electrons repel each other, and nuclei repel each other, but electrons and nuclei are attracted to each other. By convention we call the charge carried by an electron negative, and the type carried by atomic nuclei positive. The naming is arbitrary, though. If we had called the electron's charge positive and the nuclei charge negative, none of the laws of physics would be changed. **AC**




The water molecule, as a whole, has ten protons and ten electrons, making it neutral

**What is clingfilm's sticky secret?** Find out on page 82

# BRAIN DUMP

## Why is clingfilm sticky?

**Dmitry Solchenko**

Static electricity combined with clingfilm's stretchiness allows it to stick to surfaces. Clingfilm is made of a thin sheet of either PVC or low-density polyethylene. The plastic's long coiled-up molecules give it some stretch, allowing it to be pulled taut over plates or bowls. Separating the top layer of film from the roll tears electrons away from the atoms of either surface. Since electrons carry a negative charge, areas that have lost electrons end up with a positive charge, and patches that have gained electrons acquire a negative charge. The patches of electrical charge then induce an opposing charge in the surfaces they come into contact with, therefore sticking them together. **AC**

Clingfilm is frequently used to store food

## FASCINATING FACTS

### Mary's a fast cruiser

The fastest cruise ship in the world is Cunard's Queen Mary II. Its cruising speed is 26 knots (48km/h / 30mph), and it can reach a maximum speed of 30 knots (56km/h / 35mph).

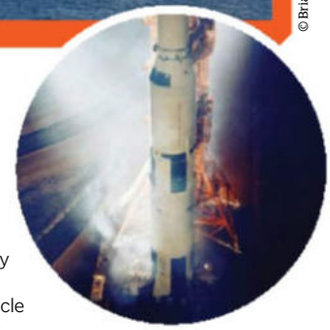


## Why do bees buzz?

**Sam Bassey**

Sound is a pressure wave transmitted through the air. When a bee is flying, it pushes down on the air with each wing beat, compressing a small patch of air. This compression ripples outward in all directions. When the oscillating pressure wave reaches your ears, you hear it as sound. The pitch is determined by how quickly the pressure oscillates up and down. Since bees beat their wings roughly 200 times a second, you hear the vibration as a 200Hz tone, which is a low buzz. **LV**

## What is the heaviest rocket ever launched?



**Ryan Jackson**

NASA's Saturn V rocket is the heaviest rocket ever launched. Used by the Apollo and Skylab programs from 1967 to 1973, it is the only launch vehicle to have carried men to the Moon. This three-stage launch vehicle had a mass of 3,000 tons and could carry a payload of 118 tons to low Earth orbit. The Saturn V is also the tallest and the most powerful rocket launched to date. Measured with the Apollo spacecraft in place on top, the Saturn V was 111 metres (363 feet) tall, 15 metres (48 feet) taller than Big Ben. **SF**

## Why don't shopping trolleys ever run straight?

**Tyler Woodforde**

Shopping trolleys are designed to move in any direction, which is undoubtedly useful when navigating the aisles of a supermarket. In some countries, including the UK, all four castors are 'floating' and therefore swivel. As a consequence, the trolley appears to have a mind of its own, often veering off in the opposite direction to where you want it to go. Some shopping trolleys, such as those found in the US, have swivel wheels only at the front and fixed wheels at the back. This mechanical design seems to offer the shopper far more control over the trolley. **SB**

## How do smoke signals work?

**Philip Smith**

To create a smoke signal, first you need fire. The purpose of a smoke signal is for it to be seen from afar, so the fire should be built on high ground in an open area. Damp grass and sticks are added to it to smother the flames and create a white smoke. A wet blanket is thrown over the fire for a trail of smoke to rise. As soon as this trail stops, the blanket must be pulled off for a white puff to be sent upward, and the blanket then put back on top of the fire. This process can be repeated to create more signals, but of course the number of smoke signals made depends on what they mean. Two puffs could mean all is well; three could mean danger. Native Americans used smoke signals to communicate quickly over long distances, with each tribe having its own system. **SB**

Noise-cancelling technology is becoming more frequent in headphones

# How do noise-cancelling headphones work?

**Francis Grant**

They use a microphone next to each ear to listen to the noises around you and then construct a sound wave that is in *antiphase* to this. If you think of a sound wave as the ridges in a ploughed field, antiphase sound is like unrolling a carpet with lumps and bumps that exactly match the contours of the field. The bumps in the carpet fill in the troughs in the soil and the result is a perfectly flat field – or in the case of headphones; silence. Noise cancelling only works well with lower frequencies so headphones also need ordinary sound insulation to block high-frequency noises. **LV**

# Why do men grow more facial hair than women?

**Tom Johnson-Moore**

Hormones dictate hair growth patterns, but the difference in hair between the sexes evolved through sexual selection. Androgens, hormones present in both males and females, cause hair to coarsen at the onset of puberty. Men have more androgens as well as testosterone, which further stimulates facial hair growth. Compared to our distant ancestors, both modern men and women are relatively hairless, but women have 'lost' more hair than men. At some point, males must have developed a preference for mating with females with less facial hair, leading bare-cheeked women to have more offspring, thereby causing female facial hair to gradually disappear. **AC**

# How do squeezy ketchup bottles work?

**Emily Burns**

Squeezy ketchup bottles rely on the fluid inside being incompressible. Imagine a plastic container of bouncy balls where the balls don't fill it. You can squeeze the container, so the balls get closer together. If the container is smaller and the balls are crammed together, it's not possible to squeeze it, as the balls occupy all of the space. However, punch a hole in the container and you can force the balls out. Similarly, if you have a bottle filled with air, you can squeeze it easily. Fill it with ketchup and you can only squeeze the bottle if there is a hole in it, allowing the ketchup to escape. **SB**

**When did the Vatican become a country?** Find out on page 84

# BRAIN DUMP

# How does compost work and why do we put it on plants?

**Anthony Charlesworth**

When plants and animals die, nature quickly starts to reclaim the abandoned resources, and the result is called compost. Bacteria, mould, flies, worms and beetles feast on decaying matter, breaking down the complex structure into reusable components.

Plants need a constant supply of nutrients for growth and repair, and unlike animals, they cannot get up to look for their food, so they take advantage of the natural process of decay to obtain the building blocks they need to survive.

On the forest floor, decaying leaf litter provides constant source of food for the plants, but often, in urban areas, plants do not get a ready supply of dead material. Adding compost to the soil helps to replace some of the nutrients that would naturally be present, allowing plants to thrive in places where they might otherwise struggle. **LM**

## FASCINATING FACTS

### Mussolini made Vatican City a country in its own right

In 1929, Italian then-prime minister Benito Mussolini wanted papal support, as the Roman Catholic Church was so powerful in Italy, so he made the Vatican a country in its own right.

### Beard and window taxes were real

The 'window tax' was in place in England from 1696 to 1851. Beard taxes were also introduced under the reigns of both Henry VIII and Peter the Great.

## How do people stay upright on unicycles?

**Abdul Khalid**

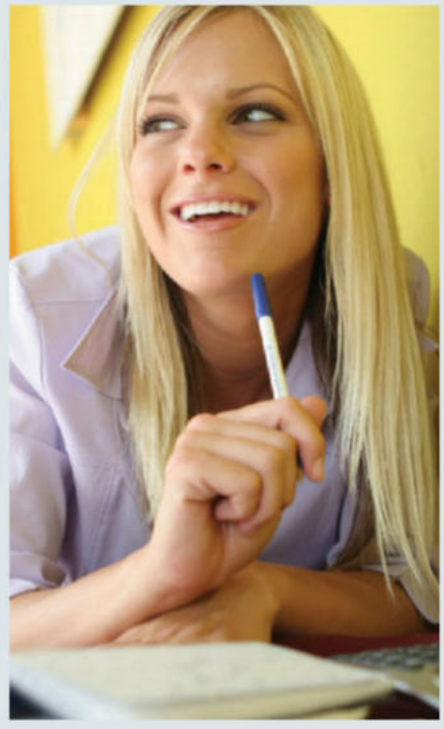
Unicyclists use their whole bodies to cycle, steer, break and balance. When travelling in a straight line, the aim is to keep their centre of gravity directly on top of the point where the wheel touches the ground, making a right angle between the seat post and the floor. The trouble is that a unicycle is impossible to keep still.

In order to balance, the unicyclist must keep pedalling, making constant adjustments forward and backward, using their arms to balance side to side. By constantly moving, they are able to keep their centre of gravity over the wheel, preventing them from toppling. **LM**

## Why does licking the top of a pen make it work again?

**Tom Huntingdon**

If you have not used a pen for a while, the ink on the ball can dry up, which means the ball won't turn. As a result, the ink can appear faded on the page or not appear at all. Licking the top of the pen moistens the ink and gets the ball rolling again, consequently getting the ink flowing. This isn't the safest or most hygienic way of making a pen work, though. Simply dabbing the nib with a moist cloth or spraying a small amount of water on it will do the trick, as well as save you from getting ink poisoning! **SB**



## What did people use to write with before ink?

**Jessica Jones**

Amazingly, ink is almost as old as writing itself, invented by both the Ancient Egyptians and the Ancient Chinese in around 2500 BCE. They combined a type of carbon known as lamp black with gum or animal glue to make a paste.

The first examples of writing appear slightly earlier, at around 5000 to 4000 BCE, and are known as the Vinca symbols. They were printed into soft clay, using lines and dots to create recognisable patterns. The Sumerians used the same technique to record what is thought to be the first true written language around 3500 BCE. **LM**

## What are the landing wheels on aeroplanes made from?

**Keith Duncan**

Aeroplane wheels undergo a lot of stress and failure can be disastrous. Because of this, they are made from a strong, light material – usually magnesium or aluminium alloy. The design of the wheel depends on factors such as the aeroplane's weight, payload and landing speed. For example, faster, lighter aeroplanes that land at high speeds are susceptible to wheel failure due to friction heating up the wheel. Because a wheel failure can send tyre fragments flying, potentially harming people and equipment, wheels on these types of planes may have a fusible plug. This safety device melts and deflates the tyre if the wheel overheats. **SF**

## Why do people say that it's too cold to snow?

**Holly O'Donaghue**

It's technically never too cold to snow, but snow is more likely to form at air temperatures around -9 to +2 degrees Celsius (16 to 36 degrees Fahrenheit). Snow forms when relatively warm, moist air rises and meets cold air, causing the water vapour to condense out and form tiny ice crystals. As they collide with other ice crystals they form fluffy snowflakes, which fall once they are heavy enough. The colder the air, the less water vapour it can hold, so the less likely it is for ice crystals and snow to form. In cold but very dry places such as Antarctica it very rarely snows. **AC**

## Which planet in the Solar System has the most gravity?

**Jessica Anderton**

The planet in our Solar System with the most gravity is also the planet with the greatest mass: Jupiter. Jupiter's gravity is about 24.79 metres (81.33 feet) per second squared – the acceleration it imparts to objects on or near its surface – versus the Earth's gravity at 9.81 metres (32.19 feet) per second squared. This means that if it were possible to stand on the surface of Jupiter (which it isn't of course, as it's a gas giant), you'd weigh about 2.5 times what you'd weigh on the Earth. Of the other rocky planets, Venus comes second to the Earth at 8.87 metres (29.10 feet) per second squared or about 90 per cent of our gravity. **SF**

## New Brain Dump is here!

Don't miss issue 17 of **Brain Dump**, the digital sister magazine to **How It Works**, which landed on the digital newsstand on 1 October. It's packed with intriguing questions and beautiful imagery. This month, you'll find out why brown bread is healthier than white, how we control the volume of our voice and what the most poisonous plant on the planet is. You'll never be short of dinner conversation with this book of fascinating facts! Download **Brain Dump** on the first of every month from iTunes or Google Play. If you have a niggling question that you want answered, then get in touch via **www.facebook.com/BraindumpMag** or Twitter @ **BrainDumpMag**.

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# Office gadgets

## The gizmos that will make your nine to five whizz by

Many of us are in the office 40 hours a week or more, so little wonder we get a bit fed up sometimes. Luckily, we've got a super range of gadgets that'll brighten up your desk and make your working day a little more bearable. Unfortunately, we haven't managed to find a boss-vanisher, but we're working on that one.

**Checklist**
- ✔ Wall decoration
- ✔ Self-stirring mug
- ✔ LED clock fan
- ✔ Desk hoover
- ✔ Multifunctional mouse pad
- ✔ Ergonomic mouse
- ✔ Solar charger


### 1 Magic mouse mat

**Multifunction mouse pad**
**£9.95 / $N/A**
**www.gizoo.co.uk**
The mouse has evolved and so has the mouse mat. This product has realised that what everyone needs is accessible USB ports, so has slapped on four of them. The actual pad feels a bit flimsy but it grips well to the table. A nicely packaged product, if a tad superfluous!
**Verdict:** ●●●●○

### 2 Cool lights

**LED clock fan**
**£19.95 / $N/A**
**www.gizoo.co.uk**
Offices can get awfully stuffy, so a desk fan can be a huge relief. They have been around for ages, so what's new about this one? It has an LED clock on it! A daft addition, because we have computers, watches and phones with the time on, but it works well and looks cool.
**Verdict:** ●●●○○

### 3 The new mouse

**Pro Wireless Ergonomic Mouse**
**£49.99 / $N/A**
**www.maplin.co.uk**
You might think the modern mouse is as good as it's going to get, but Maplin has changed the game by setting it sideways. Having your arm resting on its side does feel much more comfortable and although it does take a bit of getting used to, it's a superb evolution.
**Verdict:** ●●●●●

### 4 Stir crazy

**Self-stirring mug**
**£9.99 / $N/A**
**www.menkind.co.uk**
Sometimes, stirring that cup of tea can just be too much effort. Luckily, there is now a self-stirring mug. Finished in chrome, this mug has a small blade in the bottom that creates a whirlpool. It worked perfectly and created a well-stirred cuppa.
**Verdict:** ●●●●○

# EXTRAS

All you need to become a mobile wiz

BOOK

## 101 Solutions For Surviving Office Insanity

**Price:** £10.99 / $16.95
**Get it from:** www.amazon.com
If the joy of gadgets isn't enough to keep you from going mad at work, this excellent book from Albert J Bernstein teaches you how to deal with the 101 people and situations you'll face daily at the office.

APP

## CamScanner

**Price:** Free
**Get it from:** Google Play / iTunes
This app is one of the most popular document scanning apps on the market. It converts anything you scan into a PDF so you can view it on your phone or tablet. This is especially handy for when you're on the move a lot.

WEBSITE

## gadgetshow.channel5.com

If you're into your gadgets, this website is, obviously, chock-full of them. It's got loads of well-informed reviews, features and up-to-date news. It also contains episode guides and buying tips.

6

7

The magnets are made of neodymium, which is the most commonly used material for magnets.

The charger uses a rechargeable lithium-ion battery to store the gathered energy.

## 5 Dust buster

**Henry desk vacuum**
£11.99 / $N/A
**www.menkind.co.uk**
The miniature version of the Henry hoover sounds like the ideal product for cleaning up desk crumbs. On a flat desk it works pretty well, although several crumbs did fall back out again. The crevice tool doesn't seem to work at all, it's really loud and the attachment doesn't fit very easily.
**Verdict:** ●●○○○

## 6 Brighten up the office

**Urbio vertical garden**
£74.99 / $75
**www.2tech.co.uk / www.myurbio.com**
You can magnetically stick pots and troughs onto the wall plate and fill them with plants or office accessories. We're not that keen on them because they don't look very attractive, are too shallow for plants and it'd be an understanding boss who'd let you screw the plates into the wall. Perhaps this would be more suited as a home office organiser.
**Verdict:** ●●○○○

## 7 Mobile solar power

**XD Design Solarladefenster**
£40 / €49.95 / $N/A
**www.design-3000.de**
Solar power seems to be all the rage these days and this is a really interesting new take on the technology. Just clip the charger onto a window to begin charging. It also stores the power for future use when it's not so sunny and you need some juice.
**Verdict:** ●●●●○

# GROUP TEST
Putting products through their paces

# Bluetooth speakers

Portable, wireless speakers for music on the go

**Packing some power**
Ruark has created BackPack, a rechargeable power pack that can be attached to the speaker, giving you portable power.

**How very aptX**
The speakers use aptX technology, which enhances audio quality over Bluetooth.


## 1 Blue Aura x30

**Price:** £289 / $N/A
**Get it from:** **www.blueaura.co.uk**
The faux leather look of these speakers could split potential buyers right down the middle. We tested the Sahara-coloured version, which look pretty stylish.

The speakers themselves are excellent quality, connecting to the Bluetooth device straight away and providing a really rich sound. It has a wide volume range and the sound won't be distorted, even when the volume is whacked right up.

The remote control looks a bit of a last-minute decision, the six buttons spaced very wide apart. We felt it would look better if it was smaller and more compact, but on the plus side it is very responsive.

The Sub Out feature means the bass can be brought right up and still sound undistorted, so that's another point in its favour. The connections are a decent length and nicely unobtrusive, so won't spoil the look of the room.

We liked these speakers a lot for their overall sound quality and practicality. There are a couple of issues regarding the design, which could be quite divisive, but it's a good product, if a little pricey.
**Verdict:** ●●●●○

## 2 Ruark MR1

**Price:** £299.95 / $N/A
**Get it from:** **www.johnlewis.com**
The Ruark MR1 has attempted to bring a touch of style to the speaker world and, in our opinion, has succeeded. Finished in rich walnut, these speakers will look great in pretty much any living room.

The sound quality as well is as good as anything else we tested providing crisp and clear music and we'd say it was probably the best for the higher tones.

You can also plug devices in, but the Bluetooth connection is so good that it's not really necessary. We also liked the LED lights on the front that told you when the machine itself is on, when the Bluetooth connection is available and when it is synced up with a device. If you aren't so great at technology, this system makes it extremely easy to know precisely what isn't on at the time.

We really liked this speaker as it looked good and sounded great. There are several input options and the controls are clear, but it does lose out again because of the poorly designed remote control, and it is the most expensive of the bunch.
**Verdict:** ●●●●○

# ON THE HORIZON

More tech to show off to your friends

## LG G Watch R

LG has created the world's first circular plastic OLED display, which makes the screen really sharp while keeping the classic watch style.

## PK K'3

This paperclip-sized USB stick is the smallest in the world, able to read data at 115MB/s and write at 20MB/s.


## 3 Onbeat-500

**Price:** £89.99 / $79.99
**Get it from: www.maplin.co.uk / www.amazon.com**
Reasonably small and unobtrusive, the Onbeat-500 isn't the best-looking speaker on the market, but it is pretty good at its job.

The fastest of the bunch at turning on and connecting to the Bluetooth device, it is incredibly simplistic but plays extremely good audio. Its main drawback is the lack of controls. There is a button to turn it on, two volume buttons and nothing else, so it has to basically be operated entirely from your phone or tablet.

However, there are plenty of other very positive features with it. It is totally wireless, running off a lithium-ion battery that gives you eight hours of play time before it needs to be recharged, so it is extremely portable. Its coolest feature, though, is that the speakerphone function lets you make and receive calls through the speaker, putting an end to tinny, crackly loudspeaker calls.

Its portability, sound quality and speakerphone make up for its slightly iffy design. However, if you are looking for a subtle speaker to provide a party with its beats and not be the centre of attention, then this is a very well priced speaker for your needs.
**Verdict:** ●●●○○

## 4 Roth Oli Powa 5 MKII

**Price:** £249.95 / $N/A
**Get it from: www.richersounds.com**
As soon as you get the Roth speakers out of the box, two things hit you. The first is the weight because they are pretty heavy. The second, however, is the sleek, stylish class that they ooze. We tested the white ones and they look the epitome of modern minimalist cool with clean, rounded edges. The speaker is sizeable and provides excellent sound at all volumes.

When we cranked the bass up, you can really feel and hear the thump, without it becoming distorted. The remote control is well designed and the Bluetooth connectivity worked perfectly. In case it doesn't, there are cables for CD player, MP3 player and a TV, so there are plenty of options. The only niggle was the messy-looking plastic cables that really looked out of place with such a sleek device.

Otherwise though, this is an excellent product that provides superb sound, has plenty of options on the remote control so you don't have to hunt for your phone or get up from your sofa, and looks gorgeous as well.
**Verdict:** ●●●●●

## 5 JBL Pulse

**Price:** £179.99 / $199.95
**Get it from: www.maplin.co.uk / www.jbl.com**
Get ready to be transported to the 1970s and the height of disco fever with this really fun speaker.

The Pulse has a huge range of LED lights all around its cylindrical body that light up, change colour and generally transform it into a multicoloured disco ball.

Even though its main selling point is the awesome light display, the sound is also excellent. At both loud and quiet volumes, the sound was clear. For such a small speaker it could actually get up to a very high volume, comfortably filling the room it was being tested in, so it has the substance to go with the style.

You might be pleased to know that the lights can be turned off, so if you're using it for a more sedate purpose, it will still do the job.

The main downside to The Pulse is that, barring the light control, there are no ways of controlling the speaker other than through your Bluetooth device. A small remote control with volume and colour levels would have been really useful.

Overall an excellent product, good sound, fun lights, but let down a bit by no accessories, which you'd expect at that price.
**Verdict:** ●●●●○

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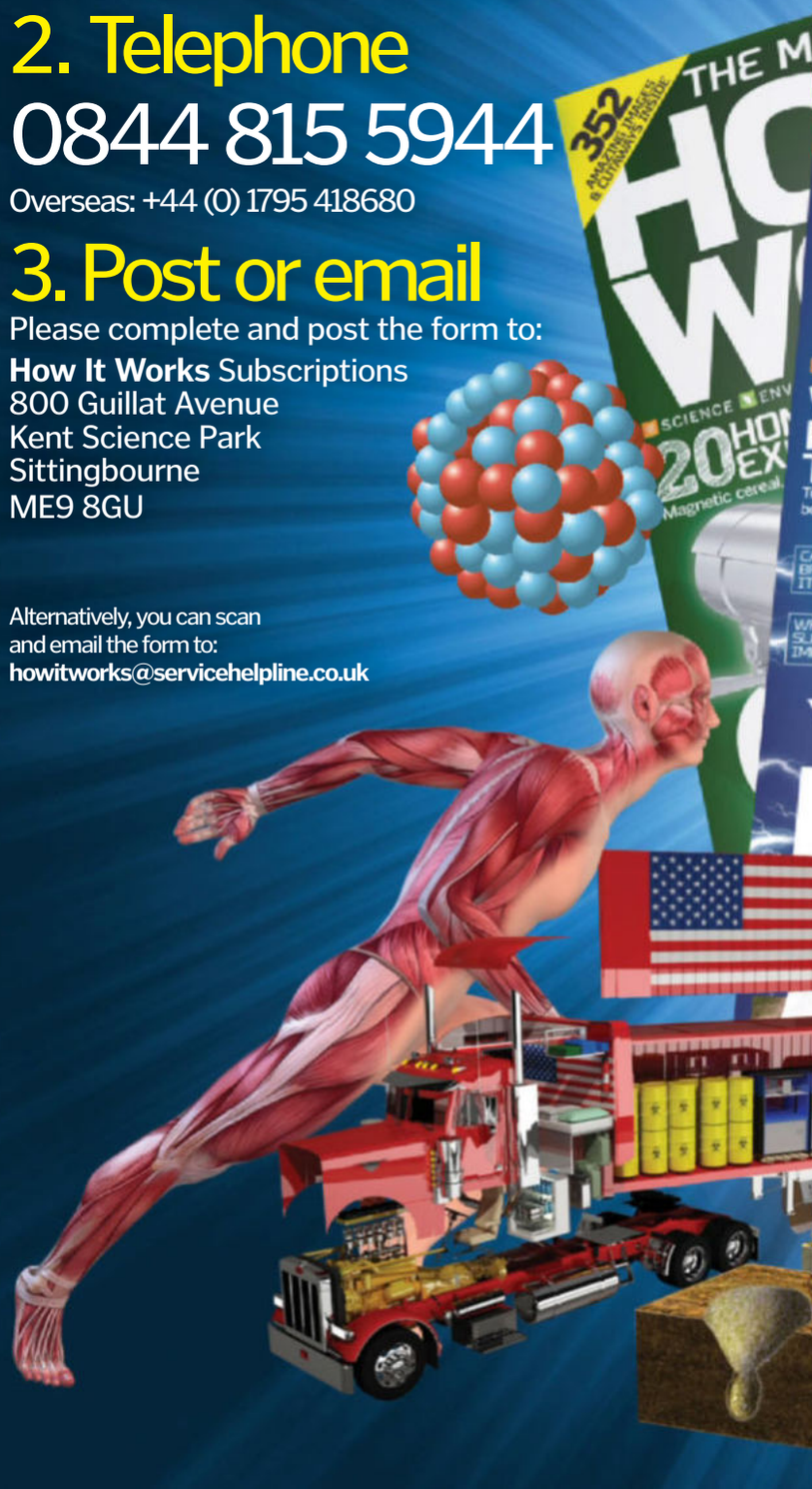

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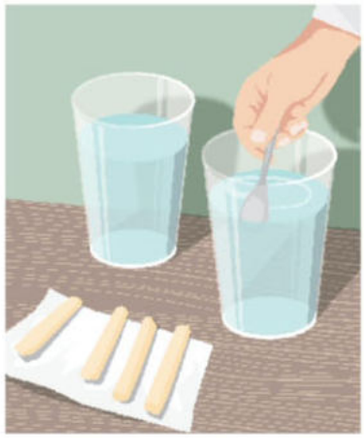
# Watch osmosis in action

See for yourself how and why water moves between different places

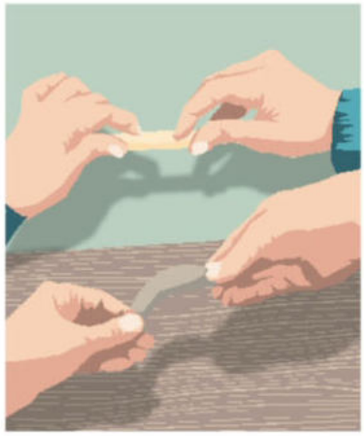


### 1 Prepare your experiment

For this experiment you'll need two glasses, distilled water, some salt and a large potato. Carefully cut the potato into slices of about three centimetres (one inch) across and fill the glasses with water. Next, place three heaped tablespoons of salt into one of the glasses. Stir until the salt is completely dissolved in the water. This means one of the glasses will have a slightly lower volume of liquid than the other.

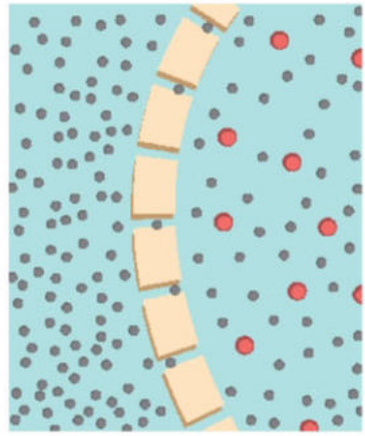

### 2 Begin osmosis

Measure your potato slices for length, width and get a feel for how firm they are. You could even take a photo of each one to remind you what colour they are before the experiment begins. Drop a potato slice into each glass of water, making sure you have labelled which of the two glasses has the salty water in it and which one contains pure water. Then you simply leave the potato slices to sit in the glasses overnight.



### 3 Observe

When you return to the glasses the next day, you should see a marked difference in the two potatoes. The one sitting in the non-salty water should look practically the same as it did the previous night, but the one in the salty glass will not look appetising at all! It should have shrunk, changed colour to a dark brown and, when you take it out, will be limp and mushy. Feel the other potato slice for comparison.



### 4 Explanation

This has happened because of osmosis. Everything in nature seeks balance and will alter its state to even out chemical differences. Water is able to escape from the potato through its skin, which is called a semi-permeable membrane. The salty water has a lower concentration of water than the potato, so to even things up, water moves from the potato into the glass of water. This increases the water content of the glass.


### 5 Other experiments

The water escaping from the potato in the salty water makes it limp and smaller because the water was what gave it its structure and size. To take this experiment further, try increasing and decreasing the amount of salt in each glass to see how dramatically rates of osmosis can be altered. You can also try different vegetables to see which ones have a semi-permeable membrane. If it doesn't change shape or colour, water has been unable to escape.

### In summary...

This experiment demonstrates how water moves across cell membranes because of osmosis. This process is vitally important to plants, as this is how they gain water through their roots. Water moves into the plant cells via the process of osmosis and makes them turgid (stiff) so the plant is able to stand upright.



NEXT ISSUE
- Make a kaleidoscope
- Create a bottled tornado

# Grow beans in cotton wool

Learn about root formation with a bean and some cotton wool

**1 Prepare your 'garden'**
Wash out a small jam jar and stuff it with cotton wool. Toilet paper can also work, but cotton wool holds water for longer. Take a couple of beans, either fresh or dried, and place them either side of the cotton wool, pressed up against the edge of the jar. Butter beans work particularly well because they are large enough for us to observe what happens, but if you don't have one, this will work with most beans and even legumes like shelled peanuts.

**2 Watch it grow**
Water the cotton wool so it is damp but not soaking wet. As the cotton wool holds the water so well, it will provide a steady source of nutrition to the bean. Place the jar in a sunny spot. The beans we eat are seeds, so they will sprout and grow a new plant just like a traditional plant seed. Within three days, you should see a root begin to grow downward from the bean. A few days later, you should be able to see spidery tendrils grow out from the bean.

**3 Taking root**
A stem should then begin to grow over the following week, pushing your bean upward and out of the jar. The roots will spread out, covering the bottom of the jar. Eventually, the bean casing will drop off and the plant will begin to grow leaves. The roots grow in any direction where they can receive water, sucking up moisture through their epidermal cells and root hairs. This water gets transferred to the main plant where it is used to help it grow.

**In summary...**
Growing a plant in a jar is an excellent way to see nature in action. The cotton wool helps it both remain stable and provide a constant source of water. Make sure the bean always has water and sunlight so it can grow before your eyes.


# QUICK QUIZ

Test your mind with ten questions based on this month's content to win an Airfix model of a Jaguar XKR GT3 car.

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. What is the HMS Queen Elizabeth's maximum speed (in km/h)?
2. Which chemical creates the smell associated with hair dye?
3. In which US state is the world's longest tunnel?
4. In what year was the iPod released?
5. As what form of quartz is agate classified?
6. What is the name of the world's oldest creosote bush colony?
7. In what year was the first commercially available hearing aid sold?
8. How many hearts does an octopus have?
9. Which crown was used for Queen Elizabeth II's coronation?
10. How many times does a hummingbird beat its wings in a second?

**ISSUE 64 ANSWERS**
**1.** Carbon dioxide **2.** Hydrophilic **3.** Graphite **4.** Cornea **5.** 4,828
**6.** Yellowstone National Park **7.** 5.8 **8.** Leonardo da Vinci
**9.** Hubert Cecil Booth **10.** 1787

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## WIN!
We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

**AMAZING PRICE FOR NEXT ISSUE'S LETTER OF THE MONTH!**

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## Letter of the Month

# Football physics

Dear **HIW**,
A football-themed question following the recent World Cup – Cristiano Ronaldo is known for his 'knuckleball' or 'knuckle shot' free kicks and it was only when I was learning to do it myself that I wondered – how does the ball move to one side in mid-air without any spin acting upon it?

Also, I would just like to say what a great magazine **How It Works** is and that I have learned so many interesting things in all different topics.

Thanks
**Patrick Clare**

**Cristiano Ronaldo's style is very different to the classic David Beckham type of free kick that puts spin on a football to help it nestle in the back of the net. The Portuguese striker's style puts little spin on the ball so a layer of airflow can engulf the ball. The ball's flight is now unpredictable and it will swerve depending on what imperfections are on its surface. When the football reaches critical velocity, its drag force decreases illustrating the increase in speed that Ronaldo seems to put on the ball midway through the ball's flight path. This allows the football to deviate wildly and outwit the opposition goalkeeper.**
**If you want to know more on this subject, check out issue 58 of our magazine where we have an article dedicated to football science and the perfect free kick.**

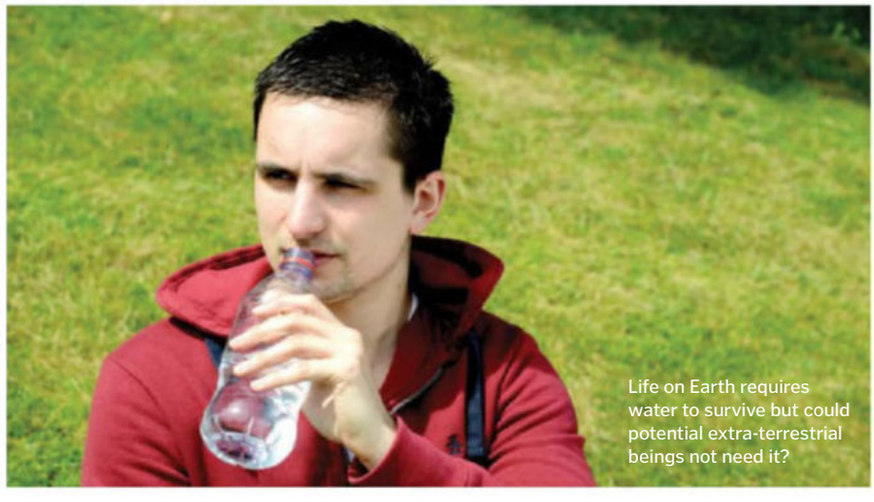
Cristiano Ronaldo is one of the best free-kick taker in the world



## Life without water?

Dear **HIW**,
In our search for life on other planets why do we assume that a life form needs $H_2O$ to survive? Humans and other creatures need it but why would an alien need it? Couldn't an alien live on the substance they breathe alone?
Thanks
**Alexander Macdougall (age 9)**
PS I think the spy gadgets magazine was awesome.

**We asked your question to Alan Penny from the School of Physics and Astronomy at the University of St Andrews and he replied: "The search looks for places where there are water, minerals and energy sources, because we think these are needed for life to come into being. If it is life like that on Earth, all life also needs those components to survive. It is possible that life could utilise another type of fluid, say liquid methane, but the exotic types of life we can think of like that seem less likely to come into being. Of course, an advanced alien life form could organise itself to use truly exotic sources of energy."**



Life on Earth requires water to survive but could potential extra-terrestrial beings not need it?

*"The original material is 'cold heated' and then cut into the designated size"*

## From 'dumbphones' to 'smartphones'

Dear **HIW**,
I always love your magazine and also have your **Book Of Technology**. I love the chunks of facts about technology, science and history. It really gets me thinking! About a week ago, I looked at the pages 28-29 in issue 63. It was about mobile phones, but I was particularly interested in a more specific subject; smartphones. What is the difference between retro mobiles and smartphones? You said the first smartphone was able to send emails, play games, have a calculator, calendar and a touchscreen, but can't retro phones have those features? What is the clear line for smartness of technology?
**Richie Han (age 11)**

**Hi Richie**
**We got in touch with Jack Parsons, Deputy Editor of Android Magazine for an answer: "The line between retro phones and smartphones isn't very clear because phones were upgraded one iteration at a time, so a few models over the years have had touch screens, the ability to surf a very basic version of the web and send emails, etc. But none of these really caught on, so the age of the smartphone really began with the launch of the iPhone in 2007. With particularly advanced touch controls that meant it didn't need physical buttons, it had the option to download basic computer programs or what we now call apps. The iPhone put the 'smart' in smartphone with real computing power. The launch of Android by Google in 2008 helped drive down the price of these new computer phones giving them mass appeal. The rest is, as they say, history."**


© Corbis

## How to make screws

Dear **HIW**,
I am first of all writing to say how delighted I am at being able to purchase **How It Works** and am currently reading issue 63 and have not missed purchasing one issue. I always look forward to the next edition at the newsagent.

I have a question: Can you explain to me how screws are manufactured as they are made in the millions yet there are so many different-size threads. It has always intrigued me so would be grateful for an answer. Thank you for this wonderful magazine.
Cheers
**Les Napper**

**Also known as a bolt or fastener, screws are incredibly useful as they hold more tightly than nails but can also be removed if something needs to be disassembled. Screws were originally hand crafted to meet the required size needed for the task. This was a slow yet articulate process and was revolutionised by the modern inventions of the screw-cutting lathe and thread rolling, which made screw production a quick and efficient process. The original material is 'cold heated' and then cut into the designated size. This creates an original screw blank, which is then designed into its final shape by thread rolling where a series of rollers mould the metal alloy into shape.**

## What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

MR LOFT @MRLOFT 15h
**@HowItWorksmag** Attached are pics outside Asda. We loved the Roman facts on pg66 but not sure Mickey Mouse would have! pic.twitter.com/Ru1z5WIw8T

Jake Savage @JakeSavage99
**@HowItWorksmag** we should definitely expand Heathrow, it's a huge global hub and needs expansion now.

Adam C @AdamTufty
**@HowItWorksmag** I live near Heathrow, and the noise now is very annoying – won't be able to put up with 3 or 4 runways!

Kieran McNairn @thekieran
**@HowItWorksmag** #translator has to be the German letter Y. Oopsilon

Mike Simpson @wordsrmagic2me
Finally got my hands on Issue 61 of **@HowItWorksmag** Well worth the wait! #knowledge #education

Aditi Rawal @a_rawal1h
Super helicopter lifts a plane! http://www.howitworksdaily.com/super-helicopter-lifts-a-plane/ ... via **@HowItWorksmag** AMAZING!

Vicki @vickitickets
**@HowItWorksmag** loved your article on giraffes, shame you didn't mention their weird little horn things.

Graeme @TheonlyBigG81
**@HowItWorksmag** Loving the mag. Ironically we were discussing maglev trains at work and how the UK should use them! #fasterthanHS2

Much and House PR
@MuchandHousePR – @MissMayim Bialik in the latest **@HowItWorksmag** It's a GREAT issue! Get your copy now!


HOW IT WORKS

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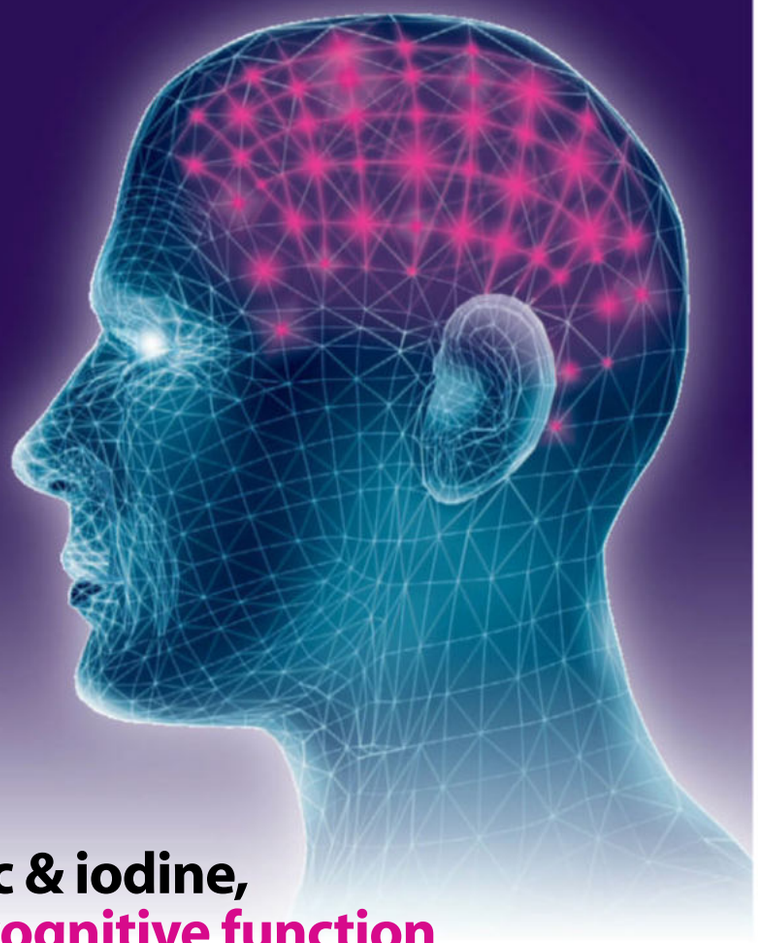

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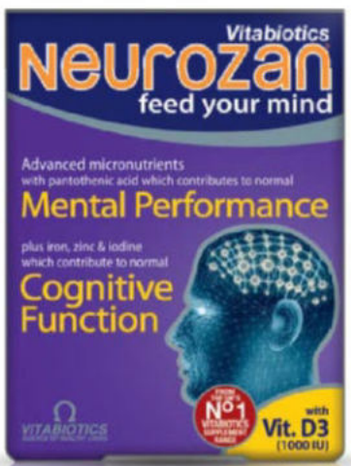


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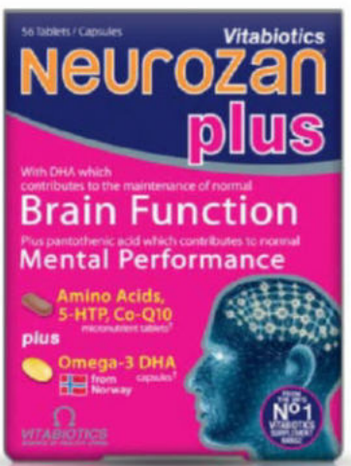


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